

Scilab Textbook Companion for
Principles Of Heat Transfer
by F. Kreith, R. M. Manglik And M. S. Bohn¹

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Book Description

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Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

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Chapter 1

Basic Modes of Heat Transfer

Scilab code Exa 1.1 Heat Loss Through a Brick Wall

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 1 Example # 1.1 ")
11
12 //Temperature Inside in F
13 Ti = 55;
14 //Temperature outside in F
15 To = 45;
16 //Thickness of the wall in ft
17 t = 1;
18 //Heat loss through the wall in Btu/h-ft2
19 q = 3.4;
20
```

```

21 //Converting Btu/h-ft2 to W/m2
22 disp("Heat loss through the wall in W/m2 is")
23 //Heat loss through the wall in W/m2
24 qdash = (q*0.2931)/0.0929
25
26 //Heat loss for a 100ft2 surface over a 24-h period
27 disp("Heat loss for a 100ft2 surface over a 24-h
    period in Btu is")
28 //Heat loss for a 100ft2 surface over a 24-h period
    in Btu
29 Q = (q*100)*24
30
31 //Q in SI units i.e. kWh
32 Q = (Q*0.2931)/1000;
33
34 //At price of 10c/kWh, the total price shall be
35 disp("So, the total price in c are")
36 //Total price in c
37 Price = 10*Q

```

Scilab code Exa 1.2 Heat Transfer Through a Window Glass

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter - 1 Example # 1.2 ")
11
12 //Thermal conductivity of window glass in W/m-K

```

```

13 k = 0.81;
14 //Height of the glass in m
15 h = 1;
16 //Width of the glass in m
17 w = 0.5;
18 //Thickness of the glass in m
19 t = 0.005;
20 //Outside temperature in C
21 T2 = 24;
22 //Inside temperature in C
23 T1 = 24.5;
24
25 //Assume that steady state exists and that the
    temperature is uniform over the inner and outer
    surfaces
26
27 //Cross sectional area in m2
28 A = h*w;
29
30 disp("Thermal resistance to conduction in K/W is")
31 //Thermal resistance to conduction in K/W
32 R = t/(k*A)
33
34 //The rate of heat loss from the interior to the
    exterior surface is
35 //obtained by dividing temperature difference from
    the thermal resistance
36
37 disp("Heat loss in W from the window glass is")
38 //Heat loss in W
39 q = (T1-T2)/R

```

Scilab code Exa 1.3 Natural Convection Between Air and Roof

1

```

2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter – 1 Example # 1.3 ")
11
12 //Area of room in m2 is given as
13 A = 20*20;
14 //Air temperature in C
15 Tair = -3;
16 //Roof temperature in C
17 Troof = 27;
18 //Heat transfer coefficient in W/m2-K
19 h = 10;
20
21 //Assume that steady state exists and the direction
      of heat flow is from the
22 //roof to the air i.e higher to lower temperature (
      as it should be).
23
24 disp(" The rate of heat transfer by convection from
      the roof to the air in W")
25 //The rate of heat transfer by convection from the
      roof to the air in W
26 q = (h*A)*(Troof-Tair)

```

Scilab code Exa 1.4 Analysis of Electrically Heated Rod

```

1
2

```

```

3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 1 Example # 1.4 ")
11
12 //Diameter of rod in m
13 d = 0.02;
14 // Emissivity and temperautre of rod in K
15 epsilon = 0.9;
16 T1 = 1000;
17 //Temperature of walls of furnace
18 T2 = 800;
19
20 //Assuming steady state has been reached.
21 //Since the walls of the furnace completely enclose
      the heating rod, all the radiant energy emitted
      by the surface of the rod is intercepted by the
      furnace walls
22
23 //From eq. 1.17, net heat loss can be given
24
25 disp("Net heat loss per unit length considering 1m
      length in W")
26 //Area in m2
27 A = (%pi*d)*1;
28 //Constant sigma in W/m2-K4
29 sigma = 0.000000567;
30 //Net heat loss per unit length considering 1m
      length in W
31 q = ((A*sigma)*epsilon)*(T1^4-T2^4)
32
33 //From eq. 1.21 radiation heat transfer coefficient
      in W/m2-K is

```

```

34 disp("Radiation heat transfer coefficient in W/m2-K
      is")
35 //Radiation heat transfer coefficient in W/m2-K
36 hr = ((epsilon*sigma)*(T1^4-T2^4))/(T1-T2)

```

Scilab code Exa 1.5 Heat Loss From a Composite Wall

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 1 Example # 1.5 ")
11
12 //Thickness of inside steel in m and thermal
      conductivity in W/m-k
13 t1 = 0.005;
14 k1 = 40;
15 //Thickness of outside brick in m and thermal
      conductivity in W/m-k
16 t2 = 0.1;
17 k2 = 2.5;
18
19 //Inside temperature in C
20 T1 = 900;
21 //Outside temperature in C
22 To = 460;
23
24 //Assuming the condition of steady state and using
      Eq. 1.24

```

```

25 disp("The rate of heat loss per unit area in W/m2
      is")
26 //The rate of heat loss per unit area in W/m2
27 qk = (T1-To)/(t1/k1+t2/k2)
28
29 disp("Temperature at the interface in K is given as"
      )
30 //Temperature at the interface in K
31 T2 = T1-(qk*t1)/k1

```

Scilab code Exa 1.6 Analysis of Aluminium Plates

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 1 Example # 1.6 ")
11
12 //Thermal conductivity of aluminium in W/m-K
13 k = 240;
14 //Thickness of each plate in m
15 t = 0.01;
16 //Temperature at the surfaces of plates in C is
      given as
17 Ts1 = 395;
18 Ts3 = 405;
19 //From Table 1.6 the contact resistance at the
      interface in K/W is
20 R2 = 0.000275;

```

```

21 //Thermal resistance of the plates in K/W is
22 R1 = t/k;
23 R3 = t/k;
24
25 disp("Heat flux in W/m2-K is")
26 //Heat flux in W/m2-K
27 q = (Ts3-Ts1)/(R1+R2+R3)
28
29 //Since the temperature drop in each section of this
    one-dimensional system is proportional to the
    resistance.
30
31 disp("Temperature drop due to contact resistance in
    degree C is")
32 //Temperature drop due to contact resistance in
    degree C
33 deltaT = (R2/(R1+R2+R3))*(Ts3-Ts1)

```

Scilab code Exa 1.7 Heat flow in Firebrick Steel System

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter - 1 Example # 1.7 ")
11
12 //Because of symmetry, we need to calculate for only
    one half of the system
13

```



```

14 //Thickness of firebrick in inches
15 L1 = 1;
16 //Thermal conductivity of firebrick in Btu/h-ft-F
17 kb = 1;
18 //Thickness of steel plate in inches
19 L3 = 1/4;
20 //Thermal conductivity of steel in Btu/h-ft-F
21 ks = 30;
22 //Average height of asperities in inches is given as
23 L2 = 1/32;
24 //Temperature difference between the steel plates in
    F is
25 deltaT = 600;
26
27
28 //The thermal resistance of the steel plate is , on
    the basis of a unit wall area, equal to
29 R3 = L3/(12*ks); //12 is added to convert ft to in
30
31 //The thermal resistance of the brick asperities is ,
    on the basis of a unit wall area, equal to
32 R4 = L2/((0.3*12)*kb); //Considering the 30 percent
    area
33
34 //At temperature of 300F, thermal conductivity of
    air in Btu/h-ft-F is
35 ka = 0.02;
36
37 // Thermal resistance of the air trapped between the
    asperities , is , on the basis of a unit area ,
    equal to
38 R5 = L2/((0.7*12)*ka); //Considering the other 70
    percent area
39
40 //Since R4 and R5 are in parallel , so there combined
    resistance is
41 R2 = (R4*R5)/(R4+R5);
42

```

```

43 //The thermal resistance of half of the solid brick
    is
44 R1 = L1/(12*kb);
45
46 //The overall unit conductance for half the
    composite wall in Btu/h-ft2-F is then
47 kk = 0.5/(R1+R2+R3);
48
49 disp("The rate of heat flow per unit area in Btu/h-
    ft2 is")
50 //The rate of heat flow per unit area in Btu/h-ft2
51 q = kk*deltaT

```

Scilab code Exa 1.8 Heat Dissipation in Instrument Circuit

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter - 1 Example # 1.8 ")
11
12 //Length for heat transfer for stainless steel in m
13 Lss = 0.1;
14
15 //Area for heat transfer for stainless steel in m2
16 A = 0.01;
17
18 //Thermal conductivity for stainless steel in W/m-K
19 kss = 144;

```

```

20
21 //Length for heat transfer for Duralumin in m
22 La1 = 0.02;
23
24 //Area for heat transfer for Duralumin in m2
25 A = 0.01;
26
27 //Thermal conductivity for Duralumin in W/m-K
28 ka1 = 164;
29
30 //Resistance in case of steel in K/W
31 Rk1 = Lss/(A*kss);
32
33 //Resistance in case of Duralumin in K/W
34 Rk2 = La1/(A*ka1);
35
36 //From Fig. 1.20, contact resistance in K/W
37 Ri = 0.05;
38
39 //Total resistance to heat transfer in K/W
40 Rtotal = Rk1+Rk2+Ri;
41
42 //Temperature diff. is given in K
43 deltaT = 40;
44
45 disp("Maximum allowable rate of heat dissipation in
      W is")
46 //Maximum allowable rate of heat dissipation in W
47 q = deltaT/Rtotal

```

Scilab code Exa 1.9 Heat Transfer Through Brick Wall

```

1
2
3 // Display mode

```

```

4 mode(0);
5
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 1 Example # 1.9 ")
11
12 //Cross sectional area in m2
13 A = 1;
14 //Heat transfer coefficient on hot side in W/m2-K
15 hchot = 10;
16 //Heat transfer coefficient on cold side in W/m2-K
17 hccold = 40;
18
19 //Length for heat transfer in m
20 L = 0.1;
21 //Thermal conductivity in W/m-K
22 k = 0.7;
23
24 //Resistances in K/w
25 R1 = 1/(hchot*A);
26 R2 = L/(k*A);
27 R3 = 1/(hccold*A);
28
29 //Total resistance
30 Rtotal = R1+R2+R3;
31
32 //Temperature on hot side in K
33 T1 = 330;
34 //Temperature on cold side in K
35 T2 = 270;
36
37 disp("Rate of heat transfer per unit area in W is")
38 //Rate of heat transfer per unit area in W
39 q = (T1-T2)/(R1+R2+R3)

```

Scilab code Exa 1.10 Heat Loss From Pipe

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 1 Example # 1.10 ")
11
12 //diameter of pipe in m
13 d = 0.5;
14 //Epsilon is given as
15 epsilon = 0.9;
16 //sigma(constant) in SI units is
17 sigma = 0.0000000567;
18 //Temperatures in K are given as
19 T1 = 500;
20 T2 = 300;
21
22 //Radiation heat transfer coefficient in W/m2K
23 hr = ((sigma*epsilon)*(T1*T1+T2*T2))*(T1+T2);
24
25 //Convection heat transfer coefficient in W/m2K
26 hc = 20;
27
28 //total heat transfer coefficient in W/m2K
29 h = hc+hr;
30
31 disp("Rate of heat loss per meter in W/m is")
```

```
32 //Rate of heat loss per meter in W/m
33 q = ((%pi*d)*h)*(T1-T2)
```

Scilab code Exa 1.11 Heat Exchanger Analysis

```
1
2
3
4 // Display mode
5 mode(0);
6
7 // Display warning for floating point exception
8 ieee(1);
9
10 clc;
11 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 1 Example # 1.11 ")
12
13 //Hot-gas temperature in K
14 Tgh = 1300;
15 //Heat transfer coefficient on hot side in W/m2K
16 h1 = 200;
17 //Heat transfer coefficient on cold side in W/m2K
18 h3 = 400;
19 //Coolant temperature in K
20 Tgc = 300;
21 //Max temp. in C
22 Tsg = 800;
23 //Maximum permissible unit thermal resistance per
      square meter of the metal wall in K/W
24 R2 = (Tgh-Tgc)/((Tgh-Tsg)/(1/h1))-1/h1-1/h3;
25 disp("Maximum permissible unit thermal resistance
      per square meter of the metal wall in m2.K/W is")
26 R2
```

Scilab code Exa 1.12 Insulation in Gas Furnace

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 1 Example # 1.12 ")
11
12 // total length of metal sheet in m
13 L = 0.625/39.4;
14 // we estimate the thermal conductivity of the
      metal sheets to be approximately 43 W/m K
15 k = 43;
16 // therefore the resistance in K/W offered by metal
      sheey
17 R = L/k;
18
19 //heat loss in W/m2 is given as
20 q = 1200;
21 // overall heat transfer coefficient between the gas
      and the door is given
22 // in W/m2K
23 U = 20;
24 //The temperature drop between the gas and the
      interior surface of the door at the specified
      heat flux is
25 deltaT1 = q/U;
26 //Hence, the temperature of the Inconel will be in
```

```

    degree C
27 T = 1200-deltaT1;
28
29 //The heat transfer coefficient between the outer
    surface of the door and
30 //the surroundings at 20 C in W/m2K
31 h = 5;
32 //The temperature drop at the outer surface in
    degree C is
33 deltaT2 = q/h;
34 //Selecting milled alumina-silica chips as insulator
    (Fig 1.31 on page 48)
35
36 // Hence, temperature difference across the
    insulation is
37 deltaT3 = T-deltaT1-deltaT2;
38
39 //thermal conductivity for milled alumina-silica
    chips in W/mK is
40 k = 0.27;
41
42 disp("The insulation thickness in m is")
43 //The insulation thickness in m
44 L = (k*deltaT3)/q

```

Scilab code Exa 1.13 Energy Balance at Roof

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8

```



```

9  clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 1 Example # 1.13 ")
11
12 //Temperature of air in degree K
13 Tair = 300;
14 //Heat transfer coefficient in W/m2K
15 h = 10;
16
17 disp("Part a")
18 //Radiation solar flux in W/m2
19 q = 500;
20 //Ambient temperature in K
21 Tsurr = 50;
22
23 disp("Solving energy balance equaiton by trial and
      error for the roof temperature , we get temp. in
      degree K")
24 //Room temperature in degree K
25 Troof = 303
26
27 disp("Part b")
28
29 //No heat flux , energy balance equaiton is modified
30 disp("Room temperature in degree K")
31 //Room temperature in degree K
32 Troof = 270

```

Scilab code Exa 1.14 Theoretical example

```

1
2
3 // Display mode
4 mode(0);
5

```

```
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 1 Example # 1.14 ")
11
12 disp("The given example is theoretical and does not
      involve any numerical computation")
```

Chapter 2

Heat Conduction

Scilab code Exa 2.1 Calculation of Heat Transfer Coefficient

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 2 Example # 2.1 ")
11
12 //Heat generation rate in W/m3
13 qg = 1000000;
14 //Length along which heat will be dissipated in m (
      thickness)
15 L = 0.01;
16 //Thermal conductivity at the required temperature
      in W/mK
17 k = 64;
18
```

```

19 //Temperature of surrounding oil in degree C
20 Tinfinity = 80;
21 //Temperature of heater in degree C to be maintained
22 T1 = 200;
23
24 disp("heat transfer coefficient in W/m2K from a heat
      balance")
25 //Heat transfer coefficient in W/m2K
26 h = ((qg*L)/2)/(T1-Tinfinity)

```

Scilab code Exa 2.2 Insulated vs Uninsulated Copper Pipe

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter – 2 Example # 2.2 ")
11
12 disp("Case of Uninsualted pipe")
13 //Calculating resistance to heat flow at internal
      surface
14
15 //Internal radius in m
16 ri = 0.05;
17 //Heat transfer coefficient at inner surface for
      steam condensing in W/m2K
18 hci = 10000;
19 //Resistance in mK/W
20 R1 = 1/(((2*%pi)*ri)*hci);

```

```

21
22 //Calculating resistance to heat flow at external
    surface
23
24 //External radius in m
25 ro = 0.06;
26 //Heat transfer coefficient at outer surface in W/
    m2K
27 hco = 15;
28 //Resistance in mK/W
29 R3 = 1/(((2*%pi)*ro)*hco);
30
31 //Calculating resistance to heat flow due to pipe
32
33 //Thermal conductivity of pipe in W/mK
34 kpipe = 400;
35 //Resistance in mK/W
36 R2 = log(ro/ri)/((2*%pi)*kpipe);
37
38 //Temperatures of steam(pipe) and surrounding(air)
    in degree C
39 Ts = 110;
40 Tinfinity = 30;
41
42 disp("Heat loss from uninsulated pipe in W/m is
    therefore")
43 //Heat loss from uninsulated pipe in W/m
44 q = (Ts-Tinfinity)/(R1+R2+R3)
45
46
47 disp("Case of insulated pipe")
48 //Calculating additional resistance between outer
    radius and new outer
49 //radius
50
51 //Thermal conductivity of insulation in W/mK
52 k = 0.2;
53 //New outer radius in m

```

```

54 r3 = 0.11;
55 //Resistance in mK/W
56 R4 = log(r3/ro)/((2*%pi)*k);
57
58 //Calculating new outer resistance
59 R0 = 1/(((2*%pi)*r3)*hco);
60
61
62 disp("Heat loss from insulated pipe in W/m is
        therefore")
63 //Heat loss from insulated pipe in W/m
64 q = (Ts-Tinfinity)/(R1+R2+R4+R0)

```

Scilab code Exa 2.3 Hot Fluid Flowing Through Pipe

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
        Kreith et. al Chapter – 2 Example # 2.3 ")
11
12 //Outer radius in m
13 ro = 0.02;
14 //Inner radius in m
15 ri = 0.015;
16 //Thermal conductivity of plastic in W/mK
17 k = 0.5;
18 //Internal convection heat transfer coefficient in W
    /m2K

```

```

19 hc1 = 300;
20 //Temperature of fluid in pipe in degree C
21 Thot = 200;
22 //Temperature of outside in degree C
23 Tcold = 30;
24 //External convection heat transfer coefficient in W
    /m2K
25 hc0 = 10;
26
27 disp("Overall heat transfer coefficient in W/m2K is"
    )
28 //Overall heat transfer coefficient in W/m2K
29 U0 = 1/(ro/(ri*hc1)+(ro*log(ro/ri))/k+1/hc0)
30
31 disp("The heat loss per unit length in W/m is")
32 //The heat loss per unit length in W/m
33 q = (((U0*2)*%pi)*ro)*(Thot-Tcold)

```

Scilab code Exa 2.4 Boiling Off Of Nitrogen

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter - 2 Example # 2.4 ")
11
12 //Temperature of liquid nitrogen in degree K
13 Tnitrogen = 77;
14 //Radius of container in m

```

```

15 ri = 0.25;
16 //Temperature of surrounding air in degree K
17 Tinfinity = 300;
18 //Thermal conductivity of insulating silica powder
   in W/mK
19 k = 0.0017;
20 //Outer radius of container with insulation in m
21 ro = 0.275;
22 //Latent heat of vaporization of liquid nitrogen in
   J/kg
23 hgf = 200000;
24 //convection coefficient at outer surface in W/m2K
25 hco = 20;
26
27 //Calculating heat transfer to nitrogen
28 q = (Tinfinity-Tnitrogen)/(1/(((4*pi)*ro)*ro)*hco)
   +(ro-ri)/(((4*pi)*k)*ro)*ri);
29
30 disp(" rate of liquid boil-off of nitrogen per hour
   is")
31 //rate of liquid boil-off of nitrogen per hour
32 m = (3600*q)/hgf

```

Scilab code Exa 2.5 Analysis of Nuclear Reactor

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp(" Principles of Heat Transfer , 7th Ed. Frank

```


Kreith et. al Chapter – 2 Example # 2.5 ”)

```
11
12 //Heat generation rate in W/m3
13 qg = 75000000;
14 //Outer radius of rods in m
15 ro = 0.025;
16 //Temperature of water in degree C
17 Twater = 120;
18 //Thermal cinductivity in W/mk
19 k = 29.5
20 //Heat transfer coefficient in W/m2K
21 hco = 55000;
22
23 //Since rate of flow through the surface of the rod
    equals the rate of internal heat generation
24 //and
25 //The rate of heat flow by conduction at the outer
    surface equals the rate
26 //of heat flow by convection from the surface to the
    water
27
28 //Surface Temperature in degree C
29 T0 = (qg*ro)/(2*hco)+Twater;
30
31 disp("Maximum temperature in degree C")
32 //Maximum temperature in degree C
33 Tmax = T0+((qg*ro)*ro)/(4*k)
```

Scilab code Exa 2.6 Analysis of Copper Pin Fin

```
1
2
3 // Display mode
4 mode(0);
5
```

```

6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 2 Example # 2.6 ")
11
12 //diameter of fin in m
13 d = 0.0025;
14 //Perimeter in m
15 P = %pi*d;
16 //Area in m2
17 A = ((%pi*d)*d)/4;
18 //Surface temperature in degree C
19 Ts = 95;
20 //Ambient temperature in degree c
21 Tinfinity = 25;
22 //Heat transfer coefficient in W/m2K
23 hc = 10;
24 //From table 12, value of thermal conductivity in W/
      mK
25 k = 396;
26
27 disp("Case of an infinitely long fin")
28 disp("Heat loss for the infintely long fin in
      W is")
29 //Heat loss for the infintely long fin in W
30 qfin = (((hc*P)*k)*A)^0.5*(Ts-Tinfinity)
31
32 disp("Case 2: Fin length of 2.5cm")
33 //Length in cm
34 L = 2.5/100;
35 //Parameter m
36 m = ((hc*P)/(k*A))^0.5;
37 disp("Heat loss in this case in W is")
38 //Heat loss in this case in W
39 qfin = qfin*((sinh(m*L)+(hc/(m*k))*cosh(m*L))/(cosh(
      m*L)+(hc/(m*k))*sinh(m*L)))

```

```

40
41 disp("For the two solutions to be within 5%")
42 //((sinh(m*L)+(hc/(m*k))*cosh(m*L))/(cosh(m*L)+(hc/(
    m*k))*sinh(m*L))) must
43 //be less than 0.95
44 disp("L must be greater than 28.3cm")

```

Scilab code Exa 2.7 Heat Loss From Circumferential Fin

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter - 2 Example # 2.7 ")
11
12 //Thermal conductivity of alumunium in W/mK
13 k = 200;
14 //Outer radius of system in m
15 ro = 5.5/200;
16 //Inner radius of system in m
17 ri = 2.5/200;
18 //Thickness of fin in m
19 t = 0.1/100;
20
21 //Temperature of pipe in degree C
22 Ts = 100;
23 //Temperature of surrounding in degree C
24 Tinfinity = 25;
25 //Heat transfer coefficient in W/m2K

```

```

26 h = 65;
27
28 //calculating fin efficiency
29 //From Fig. 2.22 on page 103, the fin efficiency is
    found to be 91%.
30
31 //Area of fin
32 A = (2*%pi)*((ro+t/2)^2-ri*ri);
33
34 disp("The rate of heat loss from a single fin in W
    is")
35 //The rate of heat loss from a single fin in W
36 q = ((0.91*h)*A)*(Ts-Tinfinity)

```

Scilab code Exa 2.8 Heat Loss From Buried Pipe

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter - 2 Example # 2.8 ")
11
12 //Diameter of pipe in m
13 D = 0.1;
14 //Depth under which it is sunk in m
15 z = 0.6;
16 //Temperature of pipe in degree C
17 Tpipe = 100;
18 //Temperature of soil in degree C

```

```

19 Tsoil = 20;
20 //Thermal conductivity in W/mK
21 k = 0.4;
22
23
24 //From table 2.2 on page 112, calculating shape
    factor
25 //Shape factor
26 S = (2*%pi)/acosh((2*z)/D);
27 disp(" rate of heat loss per meter length in W/m is"
    )
28 //rate of heat loss per meter length in W/m
29 q = (k*S)*(Tpipe-Tsoil)

```

Scilab code Exa 2.9 Heat Loss From Cubic Furnace

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter - 2 Example # 2.9 ")
11
12 //Thermal conductivity in W/mC
13 k = 1.04;
14 //For square length and breadth are equal and are in
    m
15 D = 0.5;
16 //Area in m2
17 A = D*D;

```

```

18 //Thickness in m
19 L = 0.1;
20 //Inside temperature in degree C
21 Ti = 500;
22
23 //Outside temperature in degree C
24 To = 50;
25 //Shape factor for walls
26 Sw = A/L;
27 //Shape factor for corners
28 Sc = 0.15*L;
29 //Shape factor for edges
30 Se = 0.54*D;
31
32 //There are 6 wall sections , 12 edges , and 8 corners
    , so that the total
33 //shape factor is
34 S = 6*Sw+12*Se+8*Sc;
35
36 disp("Heat flow in W is")
37 //Heat flow in W
38 q = (k*S)*(Ti-To)

```

Scilab code Exa 2.10 Transient Response of Thermocouple

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8

```

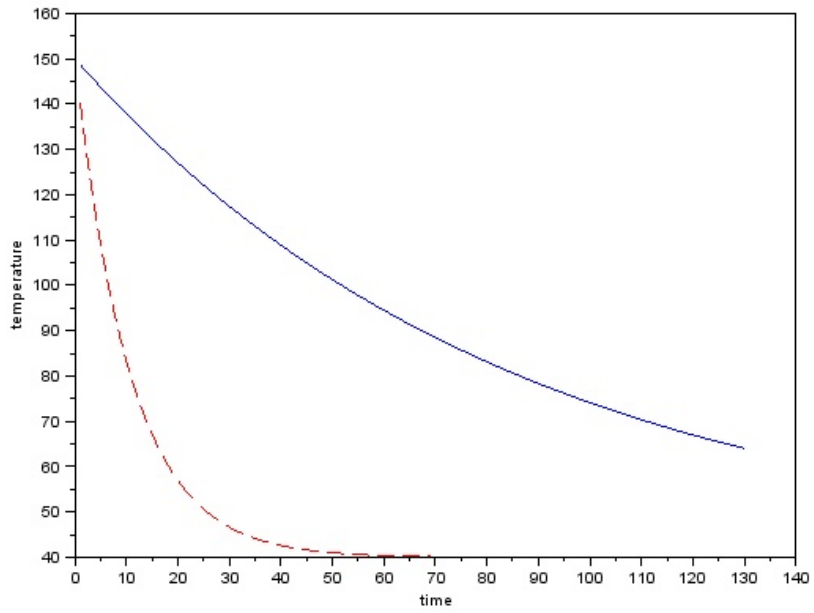


Figure 2.1: Transient Response of Thermocouple

```

9  clc;
10 disp(" Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter – 2 Example # 2.10 ")
11
12 //Diameter of copper wire in m
13 D = 0.1/100;
14 //Initial temperature in degree C
15 To = 150;
16 //Final surrounding temperature in degree C of air
      and water
17 Tinfinity = 40;
18
19 //From table 12, appendix 2, we get the following
      data values for copper
20 //Thermal conductivity in W/mK
21 k = 391;
22 //Specific heat in J/kgK
23 c = 383;
24 //Density in kg/m3
25 rho = 8930;
26
27 //Surface area of wire per unit length in m
28 A = %pi*D;
29 //Volume of wire per unit length in m2
30 V = ((%pi*D)*D)/4;
31
32 //Heat transfer coefficient in the case of water in
      W/m2K
33 h = 80;
34 //Biot number in water
35 bi = (h*D)/(4*k);
36 //The temperature response is given by Eq. (2.84)
37
38 //For water Bi*Fo is 0.0936t
39 //For air Bi*Fo is 0.0117t
40
41 for i = 1:130
42     //Position of grid

```



```

43  x(1,i) = i;
44  // Temperature of water in degree C
45  Twater(1,i) = Tinfinity+(To-Tinfinity)*exp
      (-0.0936*i);
46  // Temperature of air in degree C
47  Tair(1,i) = Tinfinity+(To-Tinfinity)*exp(-0.0117*i
      );
48  end;
49  //Plotting curve
50  plot(x,Twater,"—r")
51  set(gca(),"auto_clear","off")
52  //Plotting curve
53  plot(x,Tair)
54  //Labelling axis
55  xlabel("time")
56  ylabel("temperature")
57  disp("Temperature drop in water is more than that of
      air")

```

Scilab code Exa 2.11 Minimum Depth of Water Mains

```

1
2
3  // Display mode
4  mode(0);
5
6  // Display warning for floating point exception
7  ieee(1);
8
9  clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 2 Example # 2.11 ")
11
12 //Initial temperature of soil in degree C
13 Ti = 20;

```

```

14 //Surface temperature of soil
15 Ts = -15;
16 //Critical temperature (Freezing temperature) in
    degree C
17 Tc = 0;
18 //Time in days
19 t = 60;
20 //Density of soil in kg/m3
21 rho = 2050;
22 //Thermal conductivity of soil in W/mK
23 k = 0.52;
24 //Specific heat in J/kgK
25 c = 1840;
26 //Diffusivity in m2/sec
27 alpha = k/(rho*c);
28
29 //Finding the value of following to proceed further
30 //Z value
31 z = (Tc-Ts)/(Ti-Ts);
32
33 //From table 43, it corresponds to an error function
    value of 0.4,
34 //proceeding
35
36 disp("Minimum depth at which one must place a water
    main below the surface to avoid freezing in m is"
    )
37 //Minimum depth at which one must place a water main
    below the surface to avoid freezing in m
38 xm = (0.4*2)*((((alpha*t)*24)*3600)^0.5)

```

Scilab code Exa 2.12 Steel Component Fabrication Process

1
2

```

3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 2 Example # 2.12 ")
11
12 //Length of steel component in m
13 L = 2;
14 //Radius of steel component in m
15 ro = 0.1;
16 //Thermal conductivity of steel in W/mK
17 k = 40;
18 //Thermal diffusivity in m2/s
19 alpha = 0.00001;
20 //Initital temperature in degree C
21 Ti = 400;
22 //Surrounding temperature in degree C
23 Tinfinity = 50;
24 //Heat transfer coefficient in W/m2K
25 h = 200;
26 //time of immersion in mins
27 t = 20;
28
29 //Since the cylinder has a length 10 times the
      diameter , we can neglect end
30 //effects .
31
32 //Calculating biot number
33 bi = (h*ro)/k;
34 if bi>0.1 then
35     //Calculating fourier number
36     fo = ((alpha*t)*60)/(ro*ro);
37     //The initial amount of internal energy stored in
      the cylinder per unit

```

```

38 //length in Ws/m
39 Q = (((k*pi)*ro)*ro)*(Ti-Tinfinity))/alpha;
40
41 //The dimensionless centerline temperature for 1/
    Bi= 2.0 and Fo= 1.2 from
42 //Fig. 2.43(a)
43 //Centreline temperature in degree C
44 T = Tinfinity+0.35*(Ti-Tinfinity);
45 disp("Centreline temperature in degree C is")
46 T
47 //The surface temperature at r/r0= 1.0 and t= 1200
    s is obtained from Fig. 2.43(b) in terms of
    the centerline temperature
48 //Surface temperature in degree C
49 Tr = Tinfinity+0.8*(T-Tinfinity);
50 disp("Surface temperature in degree C is")
51 Tr
52 //Then the amount of heat transferred from the
    steel rod to the water can be obtained from Fig
    . 2.43(c). Since Q(t)/Qi= 0.61,
53 disp("The heat transferred to the water during the
    initial 20 min in Wh is")
54 //The heat transferred to the water during the
    initial 20 min in Wh
55 Q = ((0.61*L)*Q)/3600
56 end;

```

Scilab code Exa 2.13 Analysis of Concrete Wall

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception

```

```

7  ieee(1);
8
9  clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter – 2 Example # 2.13 ")
11
12 //Thickness of wall in m
13 L = 0.5;
14 //Initial temperature in degree C
15 Ti = 60;
16 //Combustion gas (Surrounding) temperature in degree
      C
17 Tinfinity = 900;
18 //Heat transfer coefficient in W/m2K
19 h = 25;
20 //Thermal conductivity in W/mk
21 k = 1.25;
22 //Specific heat in J/KgK
23 c = 837;
24 //Density in kg/m3
25 rho = 500;
26 //Thermal diffusivity in m2/s
27 alpha = 0.000003;
28 //Required temperature to achieve in degree C
29 Ts = 600;
30
31 //Calculating temperature ratio
32 z = (Ts-Tinfinity)/(Ti-Tinfinity);
33 //Reciprocal biot number
34 bi = k/(h*L);
35
36
37 //From Fig. 2.42(a) we find that for the above
      conditions the Fourier number= 0.70 at the
      midplane.
38 //Time in hours
39 t = ((0.7*L)*L)/alpha;
40 disp("Time in hours is")

```

```

41 //Time in hours
42 t = t/3600
43
44 //The temperature distribution in the wall 16 h
    after the transient was
45 //initiated can be obtained from Fig. 2.42(b) for
    various values of x/L
46
47 disp("Temperature distribution in degree C is")
48 disp(" (x/l) = 1.00 0.80 0.60 0.40 0.20")
49 disp("Fraction = 0.13 0.41 0.64 0.83 0.96")
50
51 //The heat transferred to the wall per square meter
    of surface area during
52 //the transient can be obtained from Fig. 2.42(c).
53 disp("Heat transfer in J/m2 is")
54 //Heat transfer in J/m2
55 Q = ((c*rho)*L)*(Ti-Tinfinity)

```

Scilab code Exa 2.14 Cylinder Places in Hot Oven

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter - 2 Example # 2.14 ")
11
12 //Radius of cylinder in m
13 ro = 0.05;

```

```

14 //Length of cylinder in m
15 L = 0.16;
16 //Thermal conductivity in W/mK
17 k = 0.5;
18 //Thermal diffusivity in m2/s
19 alpha = 0.0000005;
20 //Initial temperature in degree C
21 Ti = 20;
22 //Surrounding temperature in degree C
23 Tinfinity = 500;
24 //Heat transfer coefficient in W/m2K
25 h = 30;
26 //Time in mins
27 t = 30;
28
29 //Biot number
30 bi = (h*ro)/k;
31 //Fourier number
32 fo = ((alpha*t)*60)/((L*L)/4);
33
34 //From fig. 2.42(a)
35 //Po
36 P0 = 0.9;
37 //From fig. 2.42(a) and (b)
38 //Pl
39 PL = 0.243;
40 //From fig. 2.43(a)
41 //Co
42 C0 = 0.47;
43 //From fig. 2.43(a) and (b)
44 //Cr
45 CR = 0.155;
46 disp("Minimum temperature in degree C")
47 //Minimum temperature in degree C
48 Tmin = Tinfinity+((Ti-Tinfinity)*P0)*C0

```

Chapter 3

Numerical Analysis of Heat Conduction

Scilab code Exa 3.1 Temperature Distribution in Heating Element

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 3 Example # 3.1 ")
11
12 //Cross section of the element in m is given as
13 b = 0.1; //breadth in m
14 H = 0.01; //height in m
15 //Temperature of surrounding oil in C is given as
16 Tinfinity = 80;
17 //Corresponding heat transfer coefficient in W/m2-K
    is given as:
```



```

18 h = 42;
19 //Heat generation rate is given in W/m3 as
20 qg = 10^6;
21 //Temperature below which element needed to maintain
    in C is
22 T = 200;
23 // Thermal conductivity of iron in W/m-K is taken as
24 k = 64;
25
26 //Because of symmetry we need to consider only half
    of the thickness of the heating element
27 L = H/2; //Length in m
28 //We are defining five nodes at a distance of (i-1)*
    dx, where i=1,2,3,4,5
29 N = 5; //Total number of grid points
30 dx = L/(N-1); //dx in m
31 //Since no heat flows across the top face, it
    corresponds to a zero-heat
32 //flux boundary condition.
33 //Applying Eq. (2.1) to a control volume extending
    from x=L-dx/2 to x=L
34 //We get  $T_N = T_{N-1} + qg * dx * dx / (2 * k)$ 
35
36 //At the left face, , we have a surface convection
    boundary condition to which Eq. (3.7) can be
    applied
37 //Determining all the matrix coefficients in Eq.
    (3.11)
38 a1 = 1; //Matrix coefficient a1 in SI units
39 b1 = 1/(1+(h*dx)/k); //Matrix coefficient b1 in SI
    units
40 c1 = 0; //Matrix coefficient c1 in SI units
41 d1 = (dx/k)*((h*Tinfinity+(qg*dx)/2)/(1+(h*dx)/k));
    //Matrix coefficient d1 in SI units
42 a2 = 2;a3 = a2;a4 = a3;//Matrix coefficient a2 in SI
    units
43 b2 = 1;b3 = b2;b4 = b3;//Matrix coefficient b2 in SI
    units

```

```

44 c2 = 1;c3 = c2;c4 = c3;//Matrix coefficient c2 in SI
    units
45 d2 = ((dx*dx)*qg)/k;d3 = d2;d4 = d2;//Matrix
    coefficient d2 in SI units
46 a5 = 1;b5 = 0;c5 = 1;d5 = ((dx*dx)*qg)/(2*k);//
    Matrix coefficient a5 in SI units
47
48 //Using the algorithm given in Appendix 3 for
    solving the tridiagonal system, we find the
    temperature distribution given as:
49 disp("Final temperature distribution in C is the
    following")
50 //From equation 3.11
51 //Matrix A in the Appendix 3
52 A = [a1,-b1,0,0,0;
53      -c2,a2,-b2,0,0;
54      0,-c3,a3,-b3,0;
55      0,0,-c4,a4,-b4;
56      0,0,0,-c5,a5];
57 //Matrix D in the Appendix 3
58 D = [d1;d2;d3;d4;d5];
59 //Temperature matrix where temp are in degree C as
    given by appnedix 3
60 T = (A^(-1))*D

```

Scilab code Exa 3.2 Critical Depth to Avoid Freezing

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 iee(1);
8

```

```

9  clc;
10 disp(" Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 3 Example # 3.2 ")
11
12 // we have to determine minimum depth xm at which a
      water main must be buried to avoid freezing
13
14 //Initial temperature of soil in C is given as:
15 Ts = 20;
16 // Under the worst conditions anticipated it would
      be subjected to a surface
17 // temperature of -15C for a period of 60 days
18 //Max temperature in degree C
19 Tmax = -15;
20 //Time period in days
21 dt = 60;
22 //We will use the following properties for soil (at
      300 K)
23 rho = 2050; //density in kg/m3
24 k = 0.52; //thermal conductivity in W/m-K
25 c = 1840; //specific heat in J/kg-K
26 alpha = 0.138*(10^(-6)); //diffusivity in m2/sec
27
28 //Fourier number is defined as:
29 //Fo=dt*alpha/(dx*dx);
30
31 //Let us select a maximum depth of 6 m
32 //First, let us choose , giving dx=1.2m
33
34 dx = 1.2; //dx in m
35 dt = (30*24)*3600; //Days converted in seconds
36
37 //Temperature array for the old temperature in
      degree C
38 Tnew = [-15,20,20,20,20,20];
39
40 //Temperature array for the new temperature in
      degree C

```

```

41 Told = [-15,20,20,20,20,20];
42 //Fourier number is defined as:
43 Fo = (dt*alpha)/(dx*dx);
44
45 //Using eq. 3.15
46 //Initialising timestep for looping
47 timestep = 0;
48 for timestep = 0:100
49     for N = 2:4
50         //New temp in degree C
51         Tnew(N) = Told(N)+Fo*(Told(N+1)-2*Told(N)+Told(N
                    -1));
52         //Incrementing timestep
53         timestep = timestep+1;
54     end;
55 end;
56 disp("With dx=1.2m, we have the following
        distribution")
57 //New temp in degree C
58 Tnew
59
60 disp("Depth in m at which temperature would be 0
        degree C would be")
61 //Depth in m
62 xm = (0-Tnew(1)/(Tnew(2)-Tnew(1)))*dx

```

Scilab code Exa 3.3 Time Required For Cooling of Sheet

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);

```

```

8
9  clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 3 Example # 3.3 ")
11
12 //initial temperature of the sheet in C is given as:
13 Tinitial = 500;
14 //thickness of the sheet in m is given as
15 th = 0.02;
16 //density in kg/m3 is given for steel as
17 rho = 8500;
18 //specific heat in J/kg-K is given as
19 c = 460;
20 //thermal conductivity in W/m-K is given as
21 k = 20;
22 //The heat transfer coefficient in W/m2-K to the air
      is given as
23 h = 80;
24 //the ambient air temperature in degree C is
25 Tinfinity = 20;
26 //Final temperature required to achieve in C is
27 Tfinal = 250;
28 //The transient cooling of stainless steel sheet can
      be modeled as a semi-infinite slab
29 //because the thickness of the sheet is much smaller
      than its width and length.
30 L = th/2; //Length in m
31 //Finding chart solution
32 //Biot number shall be
33 Bi = (h*L)/k;
34
35 //Since Bi<0.1 and hence the sheet can be treated as
      a lumped capacitance.
36
37 //To use fig. 2.42 on page 135, we need to calculate
      the following value:
38 value = (Tfinal-Tinfinity)/(Tinitial-Tinfinity); //
      value required

```

```

39
40 //So, now using fig. 2.42, we have  $\alpha \cdot dt / (L \cdot L) = 19$ 
41 //BY the definition of thermal diffusivity ,in SI
    units we have
42 alpha = k/(rho*c);
43 disp("By chart solution , time required in seconds
    comes out to be")
44 //time required in seconds
45 t = ((19*L)*L)/alpha
46
47 //Proceeding to the numerical solution
48 //consider half the sheet thickness ,with x=0 being
    the exposed left face and
49 //x=L being the sheet center-line
50
51 //Using 20 control volumes
52 N = 21; //Total number of grid points
53 dx = L/20; //dx in m
54
55 //Old temperature array
56 for N = 1:21
57     //Old temp in degree C
58     Told(1,N) = Tinitial;
59     //New temp in degree C
60     Tnew(1,N) = Tinitial;
61 end;
62 //Initialisation Time in sec
63 t = 0;
64 //Increment of Time in sec
65 dt = 0.02;
66 //Condition of looping
67 while Told(21) > 250
68     //C1 of governing equation in SI units
69     C1 = (alpha*dt)/(dx*dx);
70     //C2 of governing equation in SI units
71     C2 = ((2*h)*dt)/((rho*c)*dx);
72     //C3 of governing equation in SI units
73     C3 = 2*C1;

```

```

74 //New temp in C as given by the equations of
    finite difference method
75 Tnew = mtlb_i(Tnew,1,Told(1)+C2*(Tinfinity-Told(1)
    )+C3*(Told(2)-Told(1)));
76 Tnew = mtlb_i(Tnew,21,Told(21)+C3*(Told(20)-Told
    (21)));
77 for N = 2:20
78 //New temp in C as given by the equations of
    finite difference method
79 Tnew = mtlb_i(Tnew,N,Told(N)+C1*(Told(N+1)-2*
    Told(N)+Told(N-1)));
80 end;
81 for N = 1:21
82 //Assigning old temp=new temp
83 Told = mtlb_i(Told,N,Tnew(N));
84 end;
85 //Modified time for new loop
86 t = t+dt;
87 end;
88 // L.67: No simple equivalent , so mtlb_fprintf() is
    called .
89 mtlb_fprintf("As per numerical solution time comes
    out to be %5.2f seconds\n",t)
90
91 disp("This time is about 1.5% less than the chart
    solution")

```

Scilab code Exa 3.4 Temperature Distribution in Rod Crosssection

```

1
2
3
4 // Display mode
5 mode(0);
6

```

```

7 // Display warning for floating point exception
8 iieee(1);
9
10 clc;
11 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 3 Example # 3.4 ")
12
13 //Dimensions of the cross section in inches
14 l = 1;
15 b = 1;
16
17 //Dividing domain such that there are four nodes in
      x and y direction
18 dx = 1/3; //dx in inches
19 dy = 1/3; //dy in inches
20
21 //Assigning Temperature in C for top and bottom
      surface
22 for i = 1:4
23     T(1,i) = 0;
24     T(4,i) = 0;
25 end;
26 //Assigning Temperature in C for side surfaces
27 for j = 1:4
28     T(j,1) = 50;
29     T(j,4) = 100;
30 end;
31 //Assigning Temperature in C for interior nodes
32 for i = 2:3
33     for j = 2:3
34         T(i,j) = 0;
35     end;
36 end;
37 //Defining looping parameter
38 step = 0;
39 for step = 0:50
40     //Using governing equations of finite difference
41     T(3,2) = 0.25*(50+0+T(2,2)+T(3,3));

```



```

42     T(2,2) = 0.25*(50+0+T(3,2)+T(2,3));
43     T(2,3) = 0.25*(100+0+T(3,2)+T(2,3));
44     T(3,3) = 0.25*(100+0+T(2,2)+T(3,3));
45 end;
46
47 //disp("At steady state , Final temperature of the
      cross section in C would be")
48 //New temp distribution in degree C
49 printf('Temperature T(2,2) in degree C is %5.2f\n',T
      (2,2))
50 printf('Temperature T(2,3) in degree C is %5.2f\n',T
      (3,2))
51 printf('Temperature T(3,2) in degree C is %5.2f\n',T
      (2,3))
52 printf('Temperature T(3,3) in degree C is %5.2f',T
      (3,3))

```

Scilab code Exa 3.5 Analysis of Alloy Bus Bar

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 3 Example # 3.5 ")
11
12 //Thermal conductivity of alloy bus bar in W/m-K is
      given as
13 k = 20;
14 //Heat generation rate in W/m3 is given as

```

```

15 qg = 10^6;
16 //dimensions of the bar in m is given as
17 L = 0.1; //Length in m
18 b = 0.05; //Width in m
19 d = 0.01; //Thickness in m
20
21 //For top edge, heat transfer coefficient in W/m2K
    and ambient temperature
22 //in C are
23 h = 75;
24 Tinfinity = 0;
25 //We are taking a total of 11 nodes in the direction
    of length and 6 nodes
26 //in the direction of width
27 dx = 0.01; //dx in m
28 dy = 0.01; //dy in m
29 //Assigning a guess temperature of 25C to all nodes
30 for i = 1:6
31     for j = 1:11
32         //Old temp. in degree C
33         Told(i,j) = 25;
34     end;
35 end;
36
37 //Assigning temperature on the left and right hand
    side
38 for i = 1:6
39     //Old temp. in degree C
40     Told(i,1) = 40;
41     Told(i,11) = 10;
42     //New temp. in degree C
43     Tnew(i,1) = 40;
44     Tnew(i,11) = 10;
45 end;
46 //Intitalisation of looping parameter
47 p = 0;
48 //Iteration to find temperature distribution
49 while p<500

```

```

50 //Equation for all interior nodes
51 for i = 2:5
52     for j = 2:10
53         //New temp. in degree C
54         Tnew(i,j) = 0.25*(Told(i-1,j)+Told(i+1,j)+Told
                    (i,j-1)+Told(i,j+1)+((qg*dx)*dx)/k);
55     end;
56 end;
57
58 //Equation for top wall
59 for j = 2:10
60     //New temp. in degree C
61     Tnew(1,j) = (h*Tinfinity+(qg*dx)/2+(k*(0.5*(Told
                    (1,j-1)+Told(1,j+1))+Told(2,j)))/dx)/(h+(2*k)
                    /dx);
62 end;
63
64 //Equation for bottom wall
65 for j = 2:10
66     //New temp. in degree C
67     Tnew(6,j) = 0.25*(Told(6,j-1)+Told(6,j+1))+0.5*
                    Told(5,j)+((qg*dx)*dx)/(4*k);
68 end;
69 for i = 1:6
70     for j = 1:11
71         //Assigning Old Temp=New Temp
72         Told(i,j) = Tnew(i,j);
73     end;
74 end;
75 //New looping parameter incremented
76 p = p+1;
77 end;
78 disp("The temperature distribution in the bar in C
        is the following")
79 //Old temp. in degree C
80 Told
81
82 //Finding maximum temperature

```

```

83 Tmax = Told(1,1);
84 for i = 1:6
85     for j = 1:11
86         if Told(i,j)>Tmax then
87             Tmax = Told(i,j);
88         else
89             Tmax = Tmax;
90         end;
91     end;
92 end;
93 disp("The maximum temperature in C in the alloy bus
      bar is")
94 //maximum temperature in C
95 Tmax
96
97 //Finding heat transfer rate
98 dz = 0.01; //dz in m
99 //Defining areas
100 for i = 2:10
101     A(1,i) = dx*dz; //Area in m2
102 end;
103 A = mtlb_i(A,1,(dx*dz)/2);
104 A = mtlb_i(A,11,A(1));
105 for i = 1:11
106     //heat transfer rate in W
107     q(1,i) = (h*A(i))*(Tnew(1,i)-Tinfinity);
108 end;
109 disp("The heat transfer rate from the top edge in W
      is given by")
110 //heat transfer rate in W
111 q

```

Scilab code Exa 3.6 Transient Behavior of Alloy Bar

1

```

2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter – 3 Example # 3.6 ")
11
12 //Thermal diffusivity in m2/s
13 alpha = 0.000008;
14 //%Thermal conductivity of alloy bus bar in W/m-K is
      given as
15 k = 20;
16 //density*specific heat product in SI units
17 pc = k/alpha;
18
19 //dimensions of the bar in m is given as
20 L = 0.1; //Length in m
21 b = 0.05; //Width in m
22 d = 0.01; //Thickness in m
23
24 //Heat generation rate in W/m3 is given as
25 qg = 10^6;
26
27 //Assigning temperature on the left and right hand
      side
28 for i = 1:6 //i is the looping parameter
29 //Old temp. in degree C
30 Told(i,1) = 40;
31 Told(i,11) = 10;
32 //New temp. in degree C
33 Tnew(i,1) = 40;
34 Tnew(i,11) = 10;
35 end;
36

```

```

37 //Assigning a guess temperature of 20C to all nodes
38 for i = 1:6//i is the looping parameter
39     for j = 1:11//j is the looping parameter
40         //Guess temp. in degree C
41         Told(i,j) = 20;
42         Tnew(i,j) = 20;
43     end;
44 end;
45
46 //Initialising time
47 m = 0;
48
49 //For top edge, heat transfer coefficient in W/m2K
    and ambient temperature
50 //in C are
51 h = 75;
52 Tinfinity = 0;
53
54 //We are taking a total of 11 nodes in the direction
    of length and 6 nodes
55 //in the direction of width
56 dx = 0.01; //dx in m
57 dy = 0.01; //dy in m
58
59 //Largest permissible time step in sec is
60 tmax = 1/((2*alpha)*(1/(dx*dx)+1/(dy*dy)));
61 //Rounding it off to nearest integer
62 t = 3; //timestep in seconds
63
64 //Condition for convergence
65 while abs(Tnew(5,6)-Told(5,6)) < 0.0001
66
67     //Equation for all interior nodes
68     for i = 2:5
69         for j = 2:10
70             //New temp. in degree C
71             Tnew(i,j) = (Told(i,j)+(alpha*t)*((Tnew(i+1,j)
                +Tnew(i-1,j))/(dx*dx)+(Tnew(i,j+1)+Tnew(i,j)

```

```

-1))/(dy*dy)+qg/k))/(1+((2*alpha)*t)*(1/(dx
*dx)+1/(dy*dy)));
72     end;
73 end;
74
75 //Equation for top wall
76 for j = 2:10
77     //New temp. in degree C
78     Tnew(1,j) = (Told(1,j)+((2*t)/((dx*dx)*pc))*(k
        *((Tnew(1,j+1)+Tnew(1,j-1))/2+Tnew(2,j)))+((
        qg*dx)*dx)/2+(h*dx)*Tinfinity)/(1+((2*t)/((dx
        *dx)*pc))*(2*k+h*dx));
79 end;
80
81 //Equation for bottom wall
82 for j = 2:10
83     //New temp. in degree C
84     Tnew(6,j) = (Told(6,j)+((2*t)/((dx*dx)*pc))*(k
        *((Tnew(6,j+1)+Tnew(6,j-1))/2+Tnew(5,j)))+((
        qg*dx)*dx)/2)/(1+((2*t)/((dx*dx)*pc))*(2*k));
85 end;
86 //New time in sec
87 m = m+t;
88 end;
89
90
91 disp("Time required to reach steady state using
    deltaT=0.3sec is 1140 seconds")

```

Scilab code Exa 3.7 Cooling of Long Cylinder

```

1
2
3 // Display mode
4 mode(0);

```

```

5
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 3 Example # 3.7 ")
11
12 // Heat Transfer coefficient is given in W/m2-K as:
13 h = 200;
14 // Radius of cylinder in m is given as:
15 R0 = 0.05;
16 // Thermal conductivity in W/m-K is given as:
17 k = 20;
18 // Thermal diffusivityt in m2/sec is given as:
19 alpha = 10^(-5);
20 // Therefore the biot number is given as:
21 Bi = (h*R0)/k;
22
23 // Ambient water bath temperature in C is given as:
24 Tinfinity = 0;
25 // Initial temperature of centre line is given as:
26 T0 = 500;
27 // Final Temperature of centre line is given as:
28 Tr = 100;
29
30 // Therefore the value of (Tr-Tinfinity)/(T0-
      Tinfinity) is:
31 value = (Tr-Tinfinity)/(T0-Tinfinity); //Required
      value
32
33 // Using above value and biot number, from Figure
      2.43 (a) on page 137, we have
34 // alpha*t/(R0*R0)=1.8
35
36 disp("Therefore from chart solution , time taken in
      seconds shall be")
37 //Time taken in seconds

```



```

38 t = ((1.8*R0)*R0)/alpha
39
40 // Proceeding to the numerical solution
41 //Because of symmetry we need to consider only one
    quarter of the circular cross section
42 //The vertical and horizontal radii are then
    adiabatic surfaces.
43
44 //We will have a total of nine types of control
    volume
45 //Each of the control volume energy balance
    equations can be solved
46
47 //The coefficient on Tfor control volume type 7 is:
48 //(dx*dx/(alpha*dt)) -2 -2*h*dx/5
49 //and for it to be positive
50
51 // value of t we use in the numerical solution must
    be smaller than this
52 // maximum value. The calculation is continued until
    the temperature for the control vol-ume nearest
    the cylinder axis is less than 100 C
53
54 disp("And using numerical solution the time in
    seconds comes out to be")
55 //Time taken in seconds
56 tfinal = 431
57 disp("which is about 4% less than the chart solution
    of 450 s.")

```

Chapter 4

Analysis of Convection Heat Transfer

Scilab code Exa 4.1 Computation of Heat Transfer Coefficient

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 4 Example # 4.1 ")
11
12 // Temperature of air in C is given as:
13 Tinfinity = 20;
14 // Temperature of surface in C is given as:
15 Ts = 100;
16 // Therefore average temperature in degree C would
    be:
17 Ta = (Ts+Tinfinity)/2;
```

```

18 // From fig. 4.2 on page 232, it can be easily seen
    that (deltaT/deltaY) at
19 // y=0 is -66.7 K/mm
20 // From Table 28 in Appendix 2, at average
    temperature of air, thermal
21 // conductivity in W/m-K is
22 k = 0.028;
23
24 //Therefore from eq. 4.1
25 disp("The heat transfer coefficient is given by, as
    per Eq. 4.1, in W/m2K")
26 // 1000 is added to convert from mm to m
27 //heat transfer coefficient in W/m2K
28 hc = ((-k*(-66.7))/(Ts-Tinfinity))*1000

```

Scilab code Exa 4.2 Theoretical Problem

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter - 4 Example # 4.2 ")
11
12 disp("The given example is theoretical and does not
    involve any numerical computation")
13
14 // Local shear stress is given as:
15 // tau=0.3*((rho*mux)^0.5)*(Uinfinity^1.5)
16

```

```

17 // Using Local friction coefficient = local shear
    stress /
18 // (0.5*rho*Uinfinity*Uinfinity), we get local
    friction coefficient as:
19
20 //disp(" Cfx = 0.6/((ReL*xstar))^0.5")
21
22 //Integrating the local value of shear stress over
    length L and dividing by
23 //area i.e. A=L*1, we get average friction
    coefficient as:
24
25 //disp(" Cfbar = 1.2/(ReL^0.5)")

```

Scilab code Exa 4.3 Flat Plate Solar Collector

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter - 4 Example # 4.3 ")
11
12 // Width of the collector plate in ft is given:
13 b = 1;
14 // Surface temperature in F is given:
15 Ts = 140;
16 // Air temperature in F is given:
17 Tinfinity = 60;
18 // Air velocity in ft/sec is given as:

```

```

19 Uinfinity = 10;
20 // Average temperature in degree F is given as:
21 T = (Ts+Tinfinity)/2;
22 // Properties of air at average temperature are as
    follows
23
24 Pr = 0.72; //Prandtl number
25 k = 0.0154; // Thermal conductivity in Btu/h ft F
26 mu = 1.285*10-5; //Viscosity in lbm/ft s
27 cp = 0.24; //Specific heat in Btu/lbm F
28 rho = 0.071; //Density in lbm/ft3
29
30 // Reynold''s number at x=1ft is
31 Re1 = ((Uinfinity*rho)*1)/mu;
32 // Reynold''s number at x=9ft is
33 Re9 = ((Uinfinity*rho)*1)/mu;
34 // Assuming that the critical Reynolds number is
    5*10^5, the critical distance is
35 //Critical Reynolds number
36 Rec = 5*(10^5);
37 //Critical distance in ft
38 xc = (Rec*mu)/(Uinfinity*rho);
39
40 // From Eq. 4.28, and using the data obtained, we
    get for part a:
41 disp("Delta at x=1ft to be 0.0213ft and at x=9ft to
    be 0.0638ft")
42
43 // From Eq. 4.30, and using the data obtained, we
    get for part b:
44 disp("Cfx at x=1ft to be 0.00283 and at x=9ft to be
    0.000942")
45
46 // From Eq. 4.31, and using the data obtained, we
    get for part c:
47 disp("Cfbar at x=1ft to be 0.00566 and at x=9ft to
    be 0.00189")
48

```

```

49 // From Eq. 4.29, and using the data obtained, we
    get for part d:
50 disp("Tau at x=1ft to be 3.12*10^-4 lb/ft^2 and at x
    =9ft to be 1.04*10^-4 lb/ft^2")
51
52 // From Eq. 4.32, and using the data obtained, we
    get for part e:
53 disp("DeltaTH at x=1ft to be 0.0237ft and at x=9ft
    to be 0.0712ft")
54
55 // From Eq. 4.36, and using the data obtained, we
    get for part f:
56 disp("hcx at x=1ft to be 1.08Btu/hft^2 F and at x=9
    ft to be 0.359Btu/hft^2 F")
57
58 // From Eq. 4.39, and using the data obtained, we
    get for part g:
59 disp("hcbars at x=1ft to be 2.18Btu/hft^2 F and at x
    =9ft to be 0.718Btu/hft^2 F")
60
61 // From Eq. 4.35, and using the data obtained, we
    get for part h:
62 disp("q at x=1ft to be 172 Btu/h and at x=9ft to be
    517 Btu/h")

```

Scilab code Exa 4.4 Heat Flow From Crankcase

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8

```

```

9  clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 4 Example # 4.4 ")
11
12 // Length of the crankcase in m is given as
13 L = 0.6;
14 // Width of the crankcase in m is given as
15 b = 0.2;
16 // Depth of the crankcase in m is given as
17 d = 0.1;
18 // Surface temperature in K is given as
19 Ts = 350;
20 // Air temperature in K is given as
21 Tinfinity = 276;
22 // Air velocity in m/sec is given as
23 Uinfinity = 30;
24 // It is stated that boundary layer is turbulent
      over the entire surface
25
26 //Average air temperature in degree K is
27 T = (Ts+Tinfinity)/2;
28 // At this average temperature, we get the following
      for air
29 rho = 1.092;//density in kg/m^3
30 mu = 0.000019123;//viscosity in SI units
31 Pr = 0.71;//Prandtl number
32 k = 0.0265;//Thermal conductivity in W/m-K
33
34 // Reynold''s number is therefore given as
35 ReL = ((rho*Uinfinity)*L)/mu;
36
37 //From eq. 4.82, average nusselt number could be
      given as
38 Nu = (0.036*(Pr^(1/3)))*(ReL^0.8);
39
40 //We can write from the basic expression , Nu=hc*L/k,
      that
41 //Heat transfer coefficient in W/m^2-K

```

```
42 hc = (Nu*k)/L;
43
44 // The surface area that dissipates heat is 0.28 m2
45 disp("Total heat loss from the surface in W is
      therefore")
46 //Heat loss from the surface in W
47 q = (hc*0.28)*(Ts-Tinfinity)
```

Chapter 5

Natural Convection

Scilab code Exa 5.1 Convection Heat Loss From Room Heater

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 5 Example # 5.1 ");
11
12 // ''Body temp in degree C''
13 Tb = 127;
14 // ''Body temp in degree K''
15 TbK = Tb+273;
16 // ''Ambient temp in degree C''
17 Ta = 27;
18 // ''Ambient temp in degree K''
19 TaK = Ta+273;
20 // ''Film temperature = (Body Temperature + Ambient
```

```

    Temperature)/2''
21 // ''Film temp in degree K''
22 TfK = (TbK+TaK)/2;
23 // ''Value of coefficient of expansion at this film
    temp in degree K inverse ''
24 B = 1/TfK;
25 // ''Value of Prandtl number at this film temp''
26 Pr = 0.71;
27 // ''Value of kinematic viscosity at this film temp
    in m2/s''
28 v = 0.0000212;
29 // ''Value of thermal conductivity at this film temp
    in W/m-K''
30 k = 0.0291;
31 // ''acceleration due to gravity in m/s2''
32 g = 9.81;
33 // ''temperature diff. between body and ambient in
    degree K''
34 deltaT = TbK-TaK;
35 // ''diameter of heater wire in m''
36 d = 0.001;
37 // ''Therefore using Rayleigh number = ((Pr*g*B*
    deltaT*d^3)/v^2)''
38 Ra = (((Pr*g)*B)*deltaT)*(d^3)/(v^2);
39
40 // ''From Fig. 5.3 on Page 303, we get''
41 // ''log(Nu) = 0.12, where Nu is nusselt number,
    therefore''
42 Nu = 1.32;
43 // ''Using Nu = hc*d/k, we get heat transfer
    coefficient in W/m2-K''
44 hc = (Nu*k)/d;
45 disp("The rate of heat loss per meter length in air
    in W/m is given by hc*(A/l)*deltaT")
46 //heat loss per meter length in air in W/m
47 q = ((hc*deltaT)*%pi)*d
48
49 // ''For Co2, we evaluate the properties at film

```

```

    temperature ''
50 // ''Following are the values of dimensionless
    numbers so obtained ''
51 // ''Rayleigh number, Ra=16.90''
52 // ''Nusselt number, Nu=1.62''
53 // ''Using Nu = hc*d/k, we get ''
54 // ''hc = 33.2 W/m2-K''
55 disp("The rate of heat loss per meter length in CO2
    is given by hc*(A/l)*deltaT")
56 disp("q = 10.4 W/m")
57
58 disp(" Discussion – For same area and temperature
    difference: ")
59 disp(" Heat transfer by convection will be more, if
    heat transfer coeff. is high")

```

Scilab code Exa 5.2 Power Requirement of Heater

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter – 5 Example # 5.2 ");
11
12 // ''Surface temp in degree C''
13 TsC = 130;
14 // ''Body temp in degree K''
15 Ts = TsC+273;
16 // ''Ambient temp in degree C''

```

```

17 TinfinityC = 20;
18 // ''Ambient temp in degree K''
19 Tinfinity = TinfinityC+273;
20 // ''Film temperature = (Surface Temperature +
    Ambient Temperature)/2''
21 // ''Film temp in degree K''
22 Tf = (Ts+Tinfinity)/2;
23 // ''Height of plate in cms''
24 L = 15;
25 // ''Width of plate in cms''
26 b = 10;
27 // ''Value of Grashof number at this film temp is
    given by
28 //65(L^3)(Ts-Tinfinity)''
29 //Grashof number
30 Gr = (65*(L^3))*(Ts-Tinfinity);
31 // ''Since the grashof number is less than 10^9,
    therefore flow is laminar''
32 // ''For air at film temp = 75C (348K), Prandtl
    number is ''
33 Pr = 0.71;
34 // ''And the product Gr*Pr is ''
35 //Product of Gr and Pr
36 GrPr = Gr*Pr;
37 // ''From Fig 5.5 on page 305, at this value of GrPr,
    Nusselt number is ''
38 Nu = 35.7;
39 // ''Value of thermal conductivity at this film temp
    in W/m-K''
40 k = 0.029;
41
42 // ''Using Nu = hc*L/k, we get ''
43 //Heat transfer coefficient for convection in W/m2-K
44 hc = (Nu*k)/(L/100);
45
46 // ''Heat transfer coefficient for radiation, hr in W
    /m2-K''
47 hr = 8.5;

```

```

48
49 // ''Total area in m2 is given by 2*(b/100)*(L/100)''
50 A = (2*(b/100))*(L/100);
51
52
53 disp("Therefore total heat transfer in W is given by
      A*(hc+hr)*(Ts-Tinfinity)")
54 //total heat transfer in W
55 q = (A*(hc+hr))*(Ts-Tinfinity)
56
57 // ''For plate to be 450cm in height , Rayleigh number
      becomes 4.62*10^11''
58 // ''which implies that the flow is turbulent''
59 // ''From Fig 5.5 on page 305, at this value of GrPr,
      Nusselt number is 973''
60 // ''Using Nu = hc*d/k, we get in W/m2-K, hc_bar
      =6.3''
61 // ''New Total area in m2, A_bar=2*(0.1)*(4.5)''
62
63 disp("Therefore in new case , total heat transfer in
      W is given by A_bar*(hc_bar+hr)*(Ts-Tinfinity)")
64 disp("we get q=1465W")
65
66
67 disp(" Discussion – For same temperature difference:
      ")
68 disp(" Heat transfer will be more, if area exposed
      for convection and radiation is more")

```

Scilab code Exa 5.3 Heat Loss From Grill

```

1
2
3 // Display mode
4 mode(0);

```

```

5
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 5 Example # 5.3 ")
11
12 // ''Surface temp in degree C''
13 TsC = 227;
14 // ''Body temp in degree K''
15 Ts = TsC+273;
16 // ''Ambient temp in degree C''
17 TinfinityC = 27;
18 // ''Ambient temp in degree K''
19 Tinfinity = TinfinityC+273;
20 // ''Film temperature = (Surface Temperature +
      Ambient Temperature)/2''
21 // ''Film temp in degree K''
22 Tf = (Ts+Tinfinity)/2;
23 // ''For a square plate, Height and width of plate in
      m''
24 L = 1;
25 b = 1;
26 // ''For a square plate, characteristic length =
      surface area/parameter in m''
27 L_bar = (L*L)/(4*L);
28 // ''Value of coefficient of expansion at this film
      temp in degree K inverse''
29 B = 1/Tf;
30 // ''Value of Prandtl number at this film temp''
31 Pr = 0.71;
32 // ''Value of thermal conductivity at this film temp
      in W/m-K''
33 k = 0.032;
34 // ''Value of kinematic viscosity at this film temp
      in m2/s''
35 v = 0.000027;

```

```

36 //''acceleration due to gravity in m/s2''
37 g = 9.81;
38 //''temperature diff. between body and ambient in
    degree K''
39 deltaT = Ts-Tinfinity;
40 //''Therefore using Rayleigh number = ((Pr*g*B*
    deltaT*(L_bar)^3)/v^2)''
41 //Rayleigh number
42 Ra = (((Pr*g)*B)*deltaT)*(L_bar^3))/(v^2);
43
44
45 //''From eq. 5.17 on page 311, we have nusselt
    number for bottom plate as 0.27*Pr^0.25''
46 NuBottom = 25.2;
47 //''From eq. 5.16 on page 311, we have nusselt
    number for top plate as 0.27*Pr^0.25''
48 NuTop = 63.4;
49 //''And therefore corresponding heat transfer
    coefficients are in W/m2-K''
50 hcBottom = (NuBottom*k)/L_bar; //heat transfer
    coefficients are in W/m2-K at bottom
51 hcTop = (NuTop*k)/L_bar; //heat transfer
    coefficients are in W/m2-K at top
52
53
54 disp("Therefore total heat transfer in W is given by
    A*(hcTop+hcBottom)*(deltaT)")
55 //heat transfer in W
56 q = ((L*b)*(hcTop+hcBottom))*deltaT

```

Scilab code Exa 5.4 Transition to Turbulent Flow in Pipe

```

1
2
3 // Display mode

```

```

4 mode(0);
5
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 5 Example # 5.4 ");
11
12 // ''Ambient temp in degree C''
13 TinfinityC = 27;
14 // ''Ambient temp in degree K''
15 Tinfinity = TinfinityC+273;
16 // ''The criterion for transition is rayleigh number
      to be 10^9''
17
18
19 // ''Value of coefficient of expansion at this temp
      in degree K inverse''
20 B = 1/Tinfinity;
21 // ''Value of Prandtl number at this ambient temp''
22 Pr = 0.71;
23 // ''Diameter of pipe in m''
24 D = 1;
25 // ''Value of kinematic viscosity at this temp in m2/
      s''
26 v = 0.0000164;
27 // ''acceleration due to gravity in m/s2''
28 g = 9.81;
29
30 // ''Therefore using Rayleigh number = ((Pr*g*B*
      deltaT*(D)^3)/v^2) = 10^9''
31 // ''we get the temperature difference in centigrade
      to be''
32 deltaT = 12;
33 disp("therefore the temperature of pipe in C is")
34 // temperature of pipe in C
35 Tpipe = TinfinityC+deltaT

```



```

36
37
38 // ''From table 13 in Appendix 2, for the case of
    water and using the same procedure we get''
39 // temperature difference in C
40 deltaTw = 0.05;
41 disp("therefore the temperature of pipe in C is")
42 // temperature of pipe in C
43 Tpipew = TinfinityC+deltaTw
44
45 disp(" Discussion – For air and water: ")
46 disp(" Temperature required to induce turbulence is
    higher in air")

```

Scilab code Exa 5.5 Rate of Heat Transfer From Burner

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter – 5 Example # 5.5 ");
11
12 // ''Top surface temp in degree C''
13 Tt = 20;
14 // ''Body temp in degree K''
15 TtK = Tt+273;
16 // ''Bottom temp in degree C''
17 Tb = 100;
18 // ''Ambient temp in degree K''

```

```

19 TbK = Tb+273;
20 // ''Average temp = (Bottom Temperature + top
    Temperature)/2''
21 // ''average temp in degree K''
22 T = (TbK+TtK)/2;
23 // ''Value of coefficient of expansion at this temp
    in degree K inverse''
24 B = 0.000518;
25 // ''Value of Prandtl number at this temp''
26 Pr = 3.02;
27 // ''Value of kinematic viscosity at this temp in m2/
    s''
28 v = 0.000000478;
29 // ''acceleration due to gravity in m/s2''
30 g = 9.8;
31 // ''temperature diff. between body and ambient in
    degree K''
32 deltaT = TbK-TtK;
33 // ''depth of water in m''
34 h = 0.08;
35 // ''Therefore using Rayleigh number = ((Pr*g*B*
    deltaT*h^3)/v^2)''
36 Ra = (((Pr*g)*B)*deltaT)*(h^3)/(v^2);
37
38 // ''From Eq. (5.30b) on page 318, we find''
39 //Nusselt number
40 Nu = 79.3;
41 // ''Value of thermal conductivity at this film temp
    in W/m-K''
42 k = 0.657;
43 // ''Using Nu = hc*d/k, we get heat transfer
    coefficient in W/m2-K''
44 hc = (Nu*k)/h;
45 // ''diameter of pan in m''
46 d = 0.15;
47 // ''area = pi*d*d/4''
48 a = ((%pi*d)*d)/4;
49 disp("The rate of heat loss in W is given by hc*(A)*

```

```

    deltaT")
50 //heat loss in W
51 q = (hc*deltaT)*a

```

Scilab code Exa 5.6 Convection Heat Transfer From Shaft

```

1
2
3
4 // Display mode
5 mode(0);
6
7 // Display warning for floating point exception
8 ieee(1);
9
10 clc;
11 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter - 5 Example # 5.6 ");
12
13 // ''RPM of shaft ''
14 N = 3;
15 // ''Angular velocity , omega=2*pi*N/60 in rad/s''
16 omega = 0.31;
17 // ''Ambient temp in degree C''
18 Ta = 20;
19 // ''Ambient temp in degree K''
20 TaK = Ta+273;
21 // ''Shaft temp in degree C''
22 Ts = 100;
23 // ''Shaft temp in degree K''
24 TsK = Ts+273;
25 // ''Film temperature = (Shaft Temperature + Ambient
    Temperature)/2''
26 // ''Film temp in degree K''
27 TfK = (TsK+TaK)/2;

```

```

28 // ''diameter of shaft in m''
29 d = 0.2;
30 // ''Value of kinematic viscosity at this film temp
    in m2/s''
31 v = 0.0000194;
32 // ''Value of reynolds number''
33 Re = (((%pi*d)*d)*omega)/v;
34
35
36 // ''acceleration due to gravity in m/s2''
37 g = 9.81;
38 // ''temperature diff. between body and ambient in
    degree K''
39 deltaT = TsK-TaK;
40 // ''Value of Prandtl number at this film temp''
41 Pr = 0.71;
42 // ''Value of coefficient of expansion at this film
    temp in degree K inverse''
43 B = 1/TfK;
44 // ''Therefore using Rayleigh number = ((Pr*g*B*
    deltaT*d^3)/v^2)''
45 //Rayleigh number
46 Ra = (((Pr*g)*B)*deltaT)*(d^3)/(v^2);
47
48 // ''From Eq. 5.35 on Page 322, we get''
49 //Nusselt number
50 Nu = 49.2;
51 // ''Value of thermal conductivity at this film temp
    in W/m-K''
52 k = 0.0279;
53 // ''Using Nu = hc*d/k, we get in W/m2-K''
54 hc = (Nu*k)/d;
55 // ''let the length exposed to heat transfer is l=1m
    ,''
56 // ''then area in m2 = pi*d*l''
57 a = %pi*d;
58 disp("The rate of heat loss in air in W is given by
    hc*(a)*deltaT")

```

```
59 //heat loss in air in W
60 q = (hc*deltaT)*a
```

Chapter 6

Forced Convection Inside Tubes and Ducts

Scilab code Exa 6.1 Heating of Water in Tube

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 6 Example # 6.1 ")
11
12 //Inlet temperature in degree C
13 Tin = 10;
14 //Outlet temperature in degree C
15 Tout = 40;
16 //Diameter in m
17 D = 0.02;
18 //Massflow rate in kg/s
```

```

19 m = 0.01;
20 //Heat flux in W/m2
21 q = 15000;
22
23 //From Table 13 in Appendix 2, the appropriate
    properties of water at an
24 //average temperature between inlet and outlet of 25
    C are
25
26 //Density in kg/m3
27 rho = 997;
28 //Specific heat in J/kgK
29 c = 4180;
30 //Thermal conductivity in W/mK
31 k = 0.608;
32 //Dynamic viscosity in Ns/m2
33 mu = 0.00091;
34
35 disp("Reynolds Number is")
36 //Reynolds number
37 Re = (4*m)/((%pi*D)*mu)
38 disp("Flow is Laminar")
39
40 //Since the thermal-boundary condition is one of
    uniform heat flux , Nu= 4.36 from Eq. (6.31)
41 //Nusselt number
42 Nu = 4.36;
43 disp("Heat transfer coefficient in W/m2K")
44 //Heat transfer coefficient in W/m2K
45 hc = (Nu*k)/D
46
47 //The length of pipe needed for a 30 C temperature
    rise is obtained from a heat balance
48 disp("Length of pipe in m")
49 //Length of pipe in m
50 L = ((m*c)*(Tout-Tin))/((%pi*D)*q)
51
52 disp("Inner surface temperature at outlet in degree

```

```

    C")
53 //Inner surface temperature at outlet in degree C
54 Ts = q/hc+Tout
55
56 //The friction factor is found from Eq. (6.18)
57 disp("Friction factor is")
58 //Friction factor is
59 f = 64/Re
60
61 //Average velocity in m/s
62 U = (4*m)/(((rho*%pi)*D)*D);
63 disp("The pressure drop in the pipe in N/m2")
64 //The pressure drop in the pipe in N/m2
65 deltaP = (((f*L)*rho)*U)*U)/(D*2)
66
67 //Efficiency
68 n = 0.5;
69 //The pumping power P is obtained from Eq. 6.19
70 disp("Pumping power in W is")
71 //Pumping power in W
72 P = (m*deltaP)/(rho*n)

```

Scilab code Exa 6.2 Recycling of Engine Oil

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter – 6 Example # 6.2 ")

```



```

11
12 //Diameter in m
13 D = 0.01;
14 //Wall thickness in m
15 t = 0.02/100;
16 //Massflow rate in kg/s
17 m = 0.05;
18 //Inlet temperature in degree C
19 Tin = 35;
20 //Outlet temperature in degree C
21 Tout = 45;
22 //Assuming a constant tube temp. in degree C
23 T = 100;
24
25 //From Table 16 in Appendix 2, we get the following
    properties for oil at
26 //40 C
27
28 //Density in kg/m3
29 rho = 876;
30 //Specific heat in J/kgK
31 c = 1964;
32 //Thermal conductivity in W/mK
33 k = 0.144;
34 //Dynamic viscosity in Ns/m2
35 mu = 0.21;
36 //Prandtl number
37 Pr = 2870;
38
39 //Reynolds Number is
40 Re = (4*m)/((%pi*D)*mu);
41
42 //For laminar flow and constant temperature
    assumption
43 //Nusselt number
44 Nu = 3.66;
45 //Heat transfer coefficient in W/m2K
46 hc = (Nu*k)/D;

```

```

47 //Heat transfer rate in W
48 q = (m*c)*(Tout-Tin);
49 //LMTD in degree K
50 LMTD = (T-Tout-(T-Tin))/log((T-Tout)/(T-Tin));
51
52 disp("Length of pipe in m is")
53 //Length of pipe in m
54 L = q/(((%pi*D)*hc)*LMTD)

```

Scilab code Exa 6.3 Flow of n Butyl Alcohol

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 6 Example # 6.3 ")
11
12 //Bulk temperature in degree K
13 T = 293;
14 //Side of square duct in m
15 b = 0.1;
16 //Length of square duct in m
17 L = 5;
18 //Wall temperature in degree K
19 Tw = 300;
20 //Velocity in m/s
21 U = 0.03;
22
23 //Hydraulic diameter in m

```

```

24 D = 4*((b*b)/(4*b));
25
26 //Physical properties at 293 K from Table 19 in
    Appendix 2 are
27
28 //Density in kg/m3
29 rho = 810;
30 //Specific heat in J/kgK
31 c = 2366;
32 //Thermal conductivity in W/mK
33 k = 0.167;
34 //Dynamic viscosity in Ns/m2
35 mu = 0.00295;
36 //Prandtl number
37 Pr = 50.8;
38
39 //Reynolds Number is
40 Re = ((U*D)*rho)/mu;
41
42 //Hence, the flow is laminar. Assuming fully
    developed flow, we get the
43 //Nusselt number for a uniform wall temperature from
    Table 6.1
44
45 Nu = 2.98;
46 //Heat transfer coefficient in W/m2K
47 hc = (Nu*k)/D;
48
49 //Similarly, from Table 6.1, the product Re*f=56.91
50
51 disp("Friction factor is")
52 //Friction factor
53 f = 56.91/Re

```

Scilab code Exa 6.4 Cooling of Electronic Device

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter – 6 Example # 6.4 ")
11
12 //Temperature of device casing in degree K
13 Ts = 353;
14 //Length of holes in m
15 L = 0.3;
16 //Diameter of holes in m
17 D = 0.00254;
18 //Inlet temperature in degree K
19 Tin = 333;
20 //Velocity in m/s
21 U = 0.2;
22
23 //The properties of water at 333 K, from Table 13 in
      Appendix 2, are
24
25 //Density in kg/m3
26 rho = 983;
27 //Specific heat in J/kgK
28 c = 4181;
29 //Thermal conductivity in W/mK
30 k = 0.658;
31 //Dynamic viscosity in Ns/m2
32 mu = 0.000472;
33 //Prandtl number
34 Pr = 3;
35
36 //Reynolds Number is

```

```

37 Re = ((U*D)*rho)/mu;
38
39 if (((Re*Pr)*D)/L)>10 then
40 //Eq. (6.42) can be used to evaluate the heat
    transfer coefficient.
41 //But since the mean bulk temperature is not known
    , we shall evaluate all the properties first at
    the inlet bulk temperature Tb1 ,
42 //then determine an exit bulk temperature, and
    then make a second iteration to obtain a more
    precise value.
43
44 //At the wall temperature of 353 K
45 //Viscosity in SI units
46 mus = 0.000352;
47 //From Eq. (6.42)
48 //Nusselt number
49 Nu = (1.86*(((Re*Pr)*D)/L)^0.33)*((mu/mus)^0.14)
    ;
50 //Heat transfer coefficient in W/m2K
51 hc = (Nu*k)/D;
52 //mass flow rate in kg/s
53 m = (((rho*pi)*D)*D)*U/4;
54
55 //Inserting the calculated values for hc and m
    into Energy balance equation, along with Tb1
    and Ts and
56 //gives Tb2=345K
57
58 //For the second iteration, we shall evaluate all
    properties at the new average bulk temperature
59 //Bulk temp. in degree C
60 Tb = (345+Tin)/2;
61
62 //At this temperature, we get from Table 13 in
    Appendix 2:
63 //Density in kg/m3
64 rho = 980;

```

```

65 //Specific heat in J/kgK
66 c = 4185;
67 //Thermal conductivity in W/mK
68 k = 0.662;
69 //Dynamic viscosity in Ns/m2
70 mu = 0.000436;
71 //Prandtl number
72 Pr = 2.78;
73
74 //New reynolds Number is
75 Re = ((U*D)*rho)/mu;
76
77 //With this value of Re, the heat transfer
    coefficient can now be calculated.
78 //We obtain the following similarly
79 //Nusselt number
80 Nu = 5.67;
81 //Heat transfer coefficient in W/m2K
82 hc = (Nu*k)/D;
83 //Similarly putting this value in energy balance
    yields
84 //Bulk temperature in degree K
85 Tb2 = 345;
86
87 disp("Outlet temperature in degree K")
88 //Outlet temperature in degree K
89 Tb2
90 end;

```

Scilab code Exa 6.5 Water Flowing in an Annulus

```

1
2
3
4 // Display mode

```

```

5 mode(0);
6
7 // Display warning for floating point exception
8 iieee(1);
9
10 clc;
11 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 6 Example # 6.5 ")
12
13 //Velocity in ft/s
14 U = 10;
15 //Outer diameter in inches
16 D = 1.5;
17 //Inner diameter in inches
18 d = 1;
19 //Temperature of water in degree F
20 Tw = 180;
21 //Temperature of wall in degree F
22 Twall = 100;
23
24 //The hydraulic diameter D for this geometry is 0.5
    in.
25 D = 0.5;
26
27 //Using properties given in the table provided
28
29 //Reynolds number
30 Re = (((U*D)*3600)*60.8)/(12*0.75);
31 //Prandtl number
32 Pr = (1*0.75)/0.39;
33 //The Nusselt number according to the Dittus-Boelter
    correlation [Eq. (6.60)]
34 Nu = (0.023*(125000^0.8))*(Pr^0.3);
35 printf('The Nusselt number according to the Dittus-
    Boelter correlation comes out to be %5.2f\n',Nu)
36
37 //Using the Sieder-Tate correlation [Eq. (6.61)]
38 //Nusselt number

```

```

39 Nu = 358;
40 printf('The Nusselt number according to the Sieder-
    Tate correlation comes out to be %5.2f\n',Nu)
41
42 //The Petukhov-Popov correlation [Eq. (6.63)] gives
43 //Friction factor
44 f = (1.82*log10(125000) - 1.64)^(-2);
45 //K1 of Eq. 6.63
46 K1 = 1+3.4*f;
47 //K2 of Eq. 6.63
48 K2 = 11.7+1.8/(Pr^0.33);
49 //Nusselt number
50 Nu = 370;
51
52 //The Sleicher-Rouse correlation [Eq. (6.64)] yields
53 //a of Eq. 6.64
54 a = 0.852;
55 //b of Eq. 6.64
56 b = 1/3+0.5/exp(0.6*4.64);
57 //Reynolds number
58 Re = 82237;
59 //Nusselt number
60 Nu = 5+(0.015*(Re^a))*(4.64^b);
61 printf('Nusselt number according to The Sleicher-
    Rouse correlation comes out to be %5.2f\n',Nu)
62
63 disp("Assuming that the correct answer is Nu=370")
64 disp("The first two correlations underpredict by
    about 10% and 3.5%, respectively")
65 disp("while the Sleicher-Rouse method overpredicts
    by about 10.5%.")

```

Scilab code Exa 6.6 Tube Length in Metal Flow

1


```

2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter – 6 Example # 6.6 ")
11
12 //Mass flow rate in kg/s
13 m = 3;
14 //Diameter of tube in m
15 D = 5/100;
16 //Temperature of fluid in degree K
17 Tb = 473;
18 //Temperature of wall in degree K
19 Ts = 503;
20
21 //Density in kg/m3
22 rho = 7700;
23 //Specific heat in J/kgK
24 c = 130;
25 //Thermal conductivity in W/mK
26 k = 12;
27 //Kinematic viscosity in m2/s
28 nu = 0.00000008;
29 //Prandtl number
30 Pr = 0.011;
31
32 //The rate of heat transfer per unit temperature
      rise in W is
33 q = (m*c)*1;
34
35 //Reynolds Number is
36 Re = (D*m)/((((rho*%pi)*D)*D)*nu)/4);
37

```

```

38 //The heat transfer coefficient in W/m2K is obtained
    from Eq. (6.67)
39 hc = ((k*0.625)*((Re*Pr)^0.4))/D;
40
41 //Surface area in m2
42 A = q/(hc*(Ts-Tb));
43
44 disp("Required length of tube in m is")
45 //Required length of tube in m
46 L = A/(%pi*D)

```

Scilab code Exa 6.7 Heat Transfer Coefficient in Circuit

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter – 6 Example # 6.7 ")
11
12 //Temperature of airstream in degree C
13 Tair = 20;
14 //Velocity of air in m/s
15 U = 1.8;
16 //Side of circuit in m
17 L = 27/1000;
18 //Spacing in the circuit in m
19 H = 17/1000;
20
21 //At 20 C , the properties of air from Table 28,

```

```

    Appendix 2, are
22
23 //Density in kg/m3
24 rho = 7700;
25 //Specific heat in J/kgK
26 c = 130;
27 //Thermal conductivity in W/mK
28 k = 0.0251;
29 //Kinematic viscosity in m2/s
30 nu = 0.0000157;
31 //Prandtl number
32 Pr = 0.011;
33
34 //Reynolds number
35 Re = (U*H)/nu;
36
37 //From Fig. (6.27), we see that the second
    integrated circuit is in the inlet region and
    estimate Nu2 =29.
38 //Nusselt number in second circuit
39 Nu2 = 29;
40 disp("Heat transfer coefficient along 2nd circuit in
    W/m2K")
41 //Heat transfer coefficient in W/m2K
42 hc2 = (Nu2*k)/L
43
44 //The sixth integrated circuit is in the developed
    region and from Eq. (6.79)
45 //Nusselt number in sixth circuit
46 Nu6 = 21.7;
47 disp("Heat transfer coefficient along 6th circuit in
    W/m2K")
48 ////Heat transfer coefficient in W/m2K
49 hc6 = (Nu6*k)/L

```

Chapter 7

Forced Convection Over Exterior Surfaces

Scilab code Exa 7.1 Heat Transfer Coefficient Over Wing

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 7 Example # 7.1 ")
11
12 //Diameter in m
13 D = 0.3;
14 //Cruising speed in m/s
15 Uinfinity = 150;
16
17 //At an altitude of 7500 m the standard atmospheric
      air pressure is 38.9 kPa and the density of the
```

```

    air is 0.566 kg/m3 (From Table 38 in Appendix 2).
18 rho = 0.566;
19 //Dynamic viscosity in kgm/s
20 mu = 0.0000174;
21 //Prandtl number
22 Pr = 0.72;
23 //Thermal conductivity in W/mK
24 k = 0.024;
25
26 //The heat transfer coefficient at the stagnation
    point (0) is, according to Eq. (7.2)
27
28 disp("Heat transfer coefficient at stagnation point
    in W/m2K")
29 //Heat transfer coefficient at stagnation point in W
    /m2K
30 h = (((k*1.14)*(((rho*Uinfinity)*D)/mu)^0.5))*(Pr
    ^0.4))/D
31
32 disp("Distribution of the convection heat trans-fer
    coefficient over the forward portion of the wing"
    )
33 for o = 0:15:75 //o is the parameter used in the
    loop
34     //convection heat trans-fer coefficients in W/
        m2K
35     ho = h*(1-(o/90)^3);
36     // L.26: No simple equivalent, so mtlb_fprintf()
        is called.
37     mtlb_fprintf("At an angle of %5.2f degree, heat
        transfer coefficient is %5.2f\n",o,ho)
38 end;

```

Scilab code Exa 7.2 Current in Hot Wire Anemometer

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 7 Example # 7.2 ")
11
12 //Diameter of wire in m
13 D = 0.000025;
14 //Length of wire in m
15 L = 0.006;
16 //Free stream temperature of air in degree C
17 T = 20;
18 //Wire temperature to be maintain in degree C
19 Tw = 230;
20 //Resistivity of platinum in ohm-cm
21 Re = 0.0000171;
22
23 //Since the wire is very thin , conduction along it
      can be neglected; also , the temperature gradient
      in the wire at any cross section can be
      disregarded.
24
25 //At freestream temperature , for air:
26
27 //Thermal conductivity in W/mC
28 k = 0.0251;
29 //Kinematic viscosity in m2/s
30 nu = 0.0000157;
31
32 //Reynolds number at velocity = 2m/s
33 Rey = (2*D)/nu;
34 if Re<40 then

```

```

35 //Using the correlation equation from Eq. (7.3)
    and Table 7.1
36 //Average convection heat transfer coefficient as
    a function of velocity
37 //is
38 //hc=799U^0.4 W/m2C
39
40 //At this point, it is necessary to estimate the
    heat transfer coefficient for radiant heat flow
    .
41 //According to Eq. (1.21), we have approximately
42 //hr=sigma*epsilon*((Ts+Tinfinity)^3)/4
43
44 //The emissivity of polished platinum from
    Appendix 2, Table 7 is about 0.05, so hr is
    about 0.05 W/m2C.
45
46 //The rate at which heat is transferred from the
    wire is therefore
47 //0.0790U^4 W.
48
49 //The electrical resistance of the wire in ohm is
50 R = ((Re*L)*4)/(((100*%pi)*D)*D);
51 end;
52
53 //A heat balance with the current i gives
54 disp("Current in ampere as a function of velocity is
    ")
55 disp(" i=0.19*U^0.2")

```

Scilab code Exa 7.3 Heat Loss From Solar Collector

```

1
2
3 // Display mode

```

```

4 mode(0);
5
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 7 Example # 7.3 ")
11
12 //Velocity of air in m/s
13 Uinfinity = 0.5;
14 //Length and breadth of square shaped array in m
15 L = 2.5;
16 //Surface temperature in degree C
17 Ts = 70;
18 //Ambient temperature in degree C
19 Ta = 20;
20
21 //At free stream temperature of air
22 //Kinematic viscosity in m2/s
23 nu = 0.0000157;
24 //Density in kg/m3
25 rho = 1.16;
26 //Specific heat in Ws/kgC
27 c = 1012;
28 //Prandtl number
29 Pr = 0.71;
30
31 //Reynolds number
32 Re = (Uinfinity*L)/nu;
33
34 //From equation 7.18
35 //The average heat transfer coefficient in W/m2C is
36 //Heat transfer coefficient in W/m2C
37 h = (((0.0033*(Pr^(-2/3)))*c)*rho)*Uinfinity;
38 disp("Heat loss from array in W is")
39 //Heat loss in W
40 q = ((h*L)*L)*(Ts-Ta)

```

Scilab code Exa 7.4 Heat Transfer Coefficient in Pipe

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 7 Example # 7.4 ")
11
12 //Diameter of pipe in m
13 D = 7.62/100;
14 //Diameter and length of cylinder in m
15 d = 0.93/100;
16 l = 1.17/100;
17 //Initial temperature in degree C
18 Ti = 50;
19 //Final temperature in degree C
20 Tf = 350;
21 //Temperature of pipe surface in degree C
22 Tp = 400;
23 //Therefore film temp. at inlet in degree C
24 Tfi = (Ti+Tp)/2;
25 //Therefore film temp. at outlet in degree C
26 Tfo = (Tf+Tp)/2;
27 //Average film temp. in degree C
28 Tf = (Tfi+Tfo)/2;
29
30 //At this film temperature
31 //Kinematic viscosity in m2/s
```

```

32 nu = 0.0000482;
33 //Thermal conductivity in W/mC
34 k = 0.042;
35 //Density in kg/m3
36 rho = 0.6;
37 //Specific heat in J/kgC
38 c = 1081;
39 //Prandtl number
40 Pr = 0.71;
41 //Flow rte of gas in kg/h is
42 m = 5;
43
44 //Superficial velocity in m/h
45 Us = m/((((rho*%pi)*D)*D)/4);
46 //Cylinder packaging volume in m3
47 V = (((%pi*d)*d)*l)/4;
48 //Surface area in m2
49 A = (((2*%pi)*d)*d)/4+(%pi*d)*l;
50 //Equivalent packaging dia in meter
51 Dp = (6*V)/A;
52
53 //REynolds number based on this dia
54 Re = ((Us*3600)*Dp)/nu;
55 //From eq. 7.23
56 disp("Heat transfer coefficient in W/m2C is")
57 //Heat transfer coefficient in W/m2C
58 h = (14.3*k)/Dp

```

Scilab code Exa 7.5 Heating of Atmospheric Air

```

1
2
3 // Display mode
4 mode(0);
5

```

```

6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 7 Example # 7.5 ")
11
12 //Initial temperature in degree F
13 Ti = 58;
14 //Final temperature in degree F
15 Tf = 86;
16 //Film temperature of air in degree F
17 Tair = (Ti+Tf)/2;
18 //Temperature of condensing steam in degree F
19 Tsteam = 212;
20 //Heat transfer coefficient in Btuh/ft2F
21 ho = 1000;
22 //Length of tube in ft
23 L = 2;
24 //Diameter of tube in in
25 d = 0.5;
26 //Wall thickness in inches
27 t = 0.049;
28 //Pitch in inches
29 p = 3/4;
30 //Width in ft and height in inches of rectangular
    shell
31 H = 15;
32 W = 2;
33 //Mass flow rate of air in lb/h
34 m = 32000;
35
36 //Appendix 2, Table 28 then gives for the properties
    of air at this mean
37 //bulk temperature
38
39 //Density in lb/ft3
40 rho = 0.072;

```

```

41 //Thermal conductivity in Btu/h F ft
42 k = 0.0146;
43 //Dynamic viscosity in lb/fth
44 mu = 0.0444;
45 //Prandtl number for air and steam
46 Pr = 0.71;
47
48 //Calculating minimum free area in ft2
49 A = ((H/p)*W)*((p-d)/12);
50 //Maximum gas velocity in lb/h.ft2
51 Gmax = m/A;
52 //Hence the reynolds number is
53 Re = (Gmax*d)/(12*mu);
54
55 //Assuming that more than 10 rows will be required ,
    the heat transfer coefficient is calculated from
    Eq. (7.29)
56
57 //h value in Btu/h ft2 F
58 h = (((k*12)/d)*(Pr0.36))*0.27*(Re0.63);
59
60 //The resistance at the steam side per tube in h F/
    Btu
61 R1 = 12/(((ho*pi)*(d-2*t))*L);
62
63 //The resistance of the pipe wall in h F/Btu
64 R2 = 0.049/(((60*pi)*L)*(d-t));
65
66 //The resistance at the outside of the tube in h F/
    Btu
67 R3 = 1/(((h*pi)*d)*L)/12);
68
69 //Total resistance in h F/Btu
70 R = R1+R2+R3;
71
72 //Mean temperature difference between air and steam
    in degree F is
73 deltaT = Tsteam-Tair;

```

```

74
75 //Specific heat of air in Btu/lb F
76 c = 0.241;
77
78 //Equating the rate of heat flow from the steam to
    the air to the rate of enthalpy rise of the air
79
80 //Solving for N gives
81 disp("Total number of transverse tubes needed are")
82 //Total number of transverse tubes
83 N = (((m*c)*(Tf-Ti))*R)/(20*deltaT)
84 disp("Rounding off = 5 tubes")
85
86 if N<10 then
87     //Correction for h value , again in Btu/h ft2 F
88     h = 0.92*h;
89 end;
90
91 //The pressure drop is obtained from Eq. (7.37) and
    Fig. 7.25.
92
93 //Velocity in ft/s
94 Umax = Gmax/(3600*rho);
95 //Acceleration due to gravity in ft/s2
96 g = 32.2;
97 disp("Corresponding pressure drop in lb/ft2")
98 //Corresponding pressure drop in lb/ft2
99 P = (((6*0.75)*rho)*Umax)*Umax)/(2*g)

```

Scilab code Exa 7.6 Pre Heating of Methane

```

1
2
3 // Display mode
4 mode(0);

```

```

5
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 7 Example # 7.6 ")
11
12 //Temperature of methane in degree C
13 T = 20;
14 //Outer dia of tube in m
15 D = 4/100;
16 //Longitudinal spacing in m
17 SL = 6/100;
18 //Transverse spacing in m
19 ST = 8/100;
20 //Wall temperature in degree C
21 Tw = 50;
22 //Methane flow velocity in m/s
23 v = 10;
24
25 //For methane at 20 C , Table 36, Appendix 2 gives
26
27 //Density in kg/m3
28 rho = 0.668;
29 //Thermal conductivity in W/mK
30 k = 0.0332;
31 //Kinematic viscosity in m2/s
32 nu = 0.00001627;
33 //Prandtl number
34 Pr = 0.73;
35
36 //From the geometry of the tube bundle , we see that
      the minimum flow
37 //area is between adjacent tubes in a row and that
      this area is half
38 //the frontal area of the tube bundle. Thus,
39 //Velocity in m/s

```

```

40 Umax = 2*v;
41
42 //Reynolds number
43 Re = (Umax*D)/nu;
44
45 //Since ST/SL<2, we use Eq. (7.30)
46
47 //Nusselt number
48 Nu = ((0.35*((ST/SL)^0.2))*(Re^0.6))*(Pr^0.36);
49
50 //Heat transfer coefficient in W/m2K
51 h = (Nu*k)/D;
52
53 //Since there are fewer than 10 rows, the
    correlation factor in Table 7.3 gives
54 disp("Heat transfer coefficient in W/m2K")
55 //Heat transfer coefficient in W/m2K
56 h = 0.92*h
57
58 //Tube–bundle pressure drop is given by Eq. (7.37).
    The insert in Fig. (7.26) gives the correction
    factor x.
59
60 disp("Corresponding pressure drop in N/m2")
61 //Corresponding pressure drop in N/m2
62 P = (((5*0.25)*rho)*Umax)*Umax)/2

```

Scilab code Exa 7.7 Analysis in Water Jet Problem

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception

```

```

7  ieee(1);
8
9  clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter – 7 Example # 7.7 ")
11
12
13 //Temperature of jet in degree C
14 T = 20;
15 //Thermal conductivity in W/mK
16 k = 0.597;
17 //Dynamic viscosity in Ns/m2
18 mu = 0.000993;
19 //Prandtl number
20 Pr = 7;
21 //Mass flow rate in kg/s
22 m = 0.008;
23 //Diameter of jet in m
24 d = 6/1000;
25 //Total heat flux in W/m2
26 q = 70000;
27
28 //Reynolds number
29 Re = (4*m)/((%pi*d)*mu);
30
31 disp("For r=3mm")
32 //From Eq. (7.45)
33 //Heat transfer coefficient in W/m2K
34 h = (63*k)/d;
35 disp("Surface temperature at r=3mm in degree C is")
36 //Surface temperature in degree C
37 Ts = T+q/h
38
39 disp("For r=12mm")
40 //From Eq. (7.48)
41 //Heat transfer coefficient in W/m2K
42 h = (35.3*k)/d;
43 disp("Surface temperature at r=12mm in degree C is")

```



```
44 //Surface temperature in degree C
45 Ts = T+q/h
```

Scilab code Exa 7.8 Analysis of Air Jet Problem

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 7 Example # 7.8 ")
11
12 //Temperature of plate in degree C
13 Tplate = 60;
14 //Temperature of jet in degree C
15 T = 20;
16 //Thermal conductivity in W/mK
17 k = 0.0265;
18 //Dynamic viscosity in Ns/m2
19 mu = 0.00001912;
20 //Prandtl number
21 Pr = 0.71;
22 //Density in kg/m3
23 rho = 1.092;
24 //Mass flow rate in kg/s
25 m = 0.008;
26 //Width of jet in m
27 w = 3/1000;
28 //Length of jet in m
29 l = 20/1000;
```

```

30 //Velocity of jet in m/s
31 v = 10;
32 //Exit distance in m
33 z = 0.01;
34 //Width given for plate in m
35 L = 0.04;
36 //Reynolds number
37 Re = ((rho*v)*w)/mu;
38
39 //From Eq. (7.68) with x= 0.02 m, z =0.01 m, and w=
    0.003 m
40 //Nusselt number
41 Nu = 11.2;
42 // ! L.33: mtlb(d) can be replaced by d() or d
    whether d is an M-file or not.
43 //Heat transfer coefficient in W/m2K
44 h = (Nu*k)/mtlb(w);
45
46 disp("Heat transfer rate from the plate in W is")
47 //Heat transfer rate from the plate in W
48 q = ((h*L)*l)*(Tplate-T)

```

Chapter 8

Heat Exchangers

Scilab code Exa 8.1 Heat Transfer Surface Area Calculations

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 8 Example # 8.1 ")
11
12 //Outer dia in m
13 d = 0.0254;
14 //mass flow rate of hot fluid in kg/s
15 mh = 6.93;
16 //Specific heat of hot fluid n J/kgK
17 ch = 3810;
18 //Inlet temperature of hot fluid in degree C
19 Thin = 65.6;
20 //Outlet temperature of hot fluid in degree C
```

```

21 Thout = 39.4;
22 //mass flow rate of cold fluid in kg/s
23 mc = 6.3;
24 //Specific heat of cold fluid n J/kgK
25 cc = 4187;
26 //Inlet temperature of cold fluid in degree C
27 Tcin = 10;
28 //Overall heat transfer coefficient in W/m2K
29 U = 568;
30
31 //Using energy balance, outlet temp. of cold fluid
   in degree C
32 Tcout = Tcin+((mh*ch)*(Thin-Thout))/(mc*cc);
33
34 //The rate of heat flow in W
35 q = (mh*ch)*(Thin-Thout);
36
37 disp("Parallel-flow tube and shell")
38 //From Eq. (8.18) the LMTD for parallel flow
39 //Temperature difference at inlet in degree K
40 deltaTa = Thin-Tcin;
41 //Temperature difference at outlet in degree K
42 deltaTb = Thout-Tcout;
43 //LMTD in degree K
44 LMTD = (deltaTa-deltaTb)/log(deltaTa/deltaTb);
45
46 //From Eq. (8.16)
47 disp("Heat transfer surface area in m2 is")
48 //Heat transfer surface area in m2
49 A = q/(U*LMTD)
50
51 disp("Counterflow tube and shell")
52 //LMTD in degree K
53 LMTD = 29.4;
54
55 disp("Heat transfer surface area in m2 is")
56 //Heat transfer surface area in m2
57 A = q/(U*LMTD)

```

```

58
59 A1 = A; //To be used further as a copy of this area
60
61 disp("Counterflow exchanger with 2 shell passes and
       72 tube passes")
62
63 //Correction factor found from Fig. 8.15 to the mean
       temperature for counterflow
64 P = (Tcout-Tcin)/(Thin-Tcin);
65 //Heat capacity ratio
66 Z = (mh*ch)/(mc*cc);
67 //From the chart of Fig. 8.15, F= 0.97
68 F = 0.97; //F-Factor
69 disp("Heat transfer surface area in m2 is")
70 //Heat transfer surface area in m2 is
71 A = A1/F
72
73 disp("Cross-flow, with one tube pass and one shell
       pass, shell-side fluid mixed")
74 //Using same procedure, we get from charts
75 F = 0.88; //F-Factor
76 disp("Heat transfer surface area in m2 is")
77 //Heat transfer surface area in m2 is
78 A = A1/F

```

Scilab code Exa 8.2 Oil Water Heat Exchanger Problem

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8

```

```

9  clc;
10 disp(" Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 8 Example # 8.2 ")
11
12 //mass flow rate of hot fluid in kg/s
13 mh = 1;
14 //Specific heat of hot fluid n J/kgK
15 ch = 2100;
16 //Inlet temperature of hot fluid in degree C
17 Thin = 340;
18 //Outlet temperature of hot fluid in degree C
19 Thout = 310;
20 //Specific heat of cold fluid n J/kgK
21 cc = 4187;
22 //Inlet temperature of cold fluid in degree C
23 Tcin = 290;
24 //Outlet temperature of cold fluid in degree C
25 Tcout = 300;
26
27 //The heat capacity rate of the water in J/kgK is ,
      from Eq. (8.14)
28 cc = ch*((Thin-Thout)/(Tcout-Tcin));
29
30 //Temperature ratio P and Z is , from Eq. (8.20)
31 P = (Thin-Thout)/(Thin-Tcin); // P Temperature ratio
32 Z = (Tcout-Tcin)/(Thin-Thout); // Z Temperature
      ratio
33
34 //From Fig. 8.14, F0.94 and the mean temperature
      difference in degree K is
35 //F Value
36 F = 0.94;
37 //Temperature difference at inlet in degree K
38 deltaTa = Thin-Tcout;
39 //Temperature difference at outlet in degree K
40 deltaTb = Thout-Tcin;
41 //LMTD in degree K
42 LMTD = (deltaTa-deltaTb)/log(deltaTa/deltaTb);

```

```

43 //Mean temperature difference in degree K
44 deltaTmean = F*LMTD;
45
46 //From Eq. (8.17) the overall conductance in W/K is
47 UA = ((mh*ch)*(Thin-Thout))/deltaTmean;
48
49 //With reference to the new conditions and Eq. 6.62
50 //Conductance in W/K
51 UA = UA*((3/4)^0.8);
52 //Number of transfer units(NTU) value
53 NTU = UA/(((3/4)*mh)*ch);
54 //Heat capacity ratio
55 K = (((3/4)*mh)*ch)/cc;
56
57 //From Fig. 8.20 the effectiveness is equal to 0.61
58 //Effectiveness
59 E = 0.61;
60 //New inlet temperature of oil in degree K
61 Toilin = 370;
62 //From eq. 8.22a
63 disp("Outlet temperature of oil in degree K")
64 //Outlet temperature of oil in degree K
65 Toilout = Toilin-E*(Toilin-Tcin)

```

Scilab code Exa 8.3 Heating of Air From Gases

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;

```

```

10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 8 Example # 8.3 ")
11
12 //Airflow rate in kg/s
13 mair = 0.75;
14 //Inlet temperature of air in degree K
15 Tairin = 290;
16 //Hot gas flow rate in kg/s
17 mgas = 0.6;
18 //Inlet temperature of hot gases in degree K
19 Tgasin = 1150;
20 //wetted perimeter on air side in m
21 Pa = 0.703;
22 //wetted perimeter on gas side in m
23 Pg = 0.416;
24 //cross-sectional area of gas passage (per passage)
      in m2
25 Ag = 0.0016;
26 //cross-sectional area of air passage (per passage)
      in m2
27 Aa = 0.002275;
28 //heat transfer surface area in m2
29 A = 2.52;
30
31 //Given that unit is of the cross-flow type, with
      both fluids unmixed.
32
33 //length of air duct in m
34 La = 0.178;
35 //hydraulic diameter of air duct in m
36 Dha = (4*Aa)/Pa;
37 //length of gas duct in m
38 Lg = 0.343;
39 //hydraulic diameter of gas duct in m
40 Dhg = (4*Ag)/Pg;
41
42 //The heat transfer coefficients can be evaluated
      from Eq. (6.63) for flow

```



```

43 //in ducts.
44 //Heat transfer coefficient for air in W/m2K
45 ha = La/Dha;
46 //Heat transfer coefficient for gas in W/m2K
47 hg = Lg/Dhg;
48
49 //Assuming the average air-side bulk temperature to
    be 573 K and the average
50 //gas-side bulk temperature to be 973 K, the
    properties at those temperatures are, from
    Appendix 2, Table 28.
51
52 //Specific heat of air in J/kgK
53 cair = 1047;
54 //Thermal conductivity of air in W/mK
55 kair = 0.0429;
56 //Dynamic viscosity of air in Ns/m2
57 muair = 0.0000293;
58 //Prandtl number of air
59 Prair = 0.71;
60
61 //Specific heat of hot gas in J/kgK
62 cgas = 1101;
63 //Thermal conductivity of hot gas in W/mK
64 kgas = 0.0623;
65 //Dynamic viscosity of hot gas in Ns/m2
66 mugas = 0.00004085;
67 //Prandtl number of hot gas
68 Prgas = 0.73;
69
70 //The mass flow rates per unit area in kg/m2s
71 //mass flow rate of air in kg/m2s
72 mdotair = mair/(19*Aa);
73 //mass flow rate of gas in kg/m2s
74 mdotgas = mgas/(18*Ag);
75
76 //The Reynolds numbers are
77 //Reynolds number for air

```

```

78 Reair = (mdotair*Dha)/muair;
79 //Reynolds number for gas
80 Regas = (mdotgas*Dhg)/mugas;
81
82 //Using Eq. (6.63), the average heat transfer
   coefficients in W/m2K
83 hair = (((0.023*kair)*(Reair^0.8))*(Prair^0.4))/Dha;
84
85 //Since La/DHa=13.8, we must correct this heat
   transfer coefficient for
86 //entrance effects, per Eq. (6.68). The correction
   factor is 1.377.
87 //Corrected heat transfer coefficient of air in W/
   m2K
88 hair = 1.377*hair;
89
90 //Similarly for hot gas
91 //Heat transfer coefficient in W/m2K
92 hgas = (((0.023*kgas)*(Regas^0.8))*(Prgas^0.4))/Dhg;
93 //Correction factor=1.27;
94 //Corrected heat transfer coefficient of gas in W/
   m2K
95 hgas = 1.27*hgas;
96
97 //Overall conductance in W/K
98 UA = 1/(1/(hair*A)+1/(hgas*A));
99
100 //The number of transfer units, based on the gas,
   which has the smaller heat capacity rate
101 NTU = UA/(mgas*cgas);
102
103 //The heat capacity-rate ratio
104 Z = (mgas*cgas)/(mair*cair);
105
106 //and from Fig. 8.21, the effectiveness is
   approximately 0.13.
107 //Effectiveness
108 E = 0.13;

```

```

109
110 disp(" Gas outlet temperature in degree K")
111 //Gas outlet temperature in degree K
112 Tgasout = Tgasin-E*(Tgasin-Tairin)
113
114 disp(" Air outlet temperature in degree K")
115 //Gas outlet temperature in degree K
116 Tairout = Tairin+(Z*E)*(Tgasin-Tairin)

```

Scilab code Exa 8.4 Heating Seawater From Condenser

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp(" Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 8 Example # 8.4 ")
11
12 //Pressure of steam in inches of Hg
13 P = 4;
14 //At this pressure , temperture of condensing steam
      in degree F
15 Thin = 125.4;
16
17 //Flow rate of seawater in lb/s
18 mw = 25000;
19 //Specific heat of water in Btu/lb F
20 c = 0.95;
21 //Inlet and outlet temperature of seawater in degree
      F

```

```

22 Tcin = 60;
23 Tcout = 110;
24 //Heat transfer coefficient of steam in Btu/h ft2 F
25 hsteam = 600;
26 //Heat transfer coefficient of water in Btu/h ft2 F
27 hwater = 300;
28 //Outer diameter in inches
29 OD = 1.125;
30 //Inner diameters in inches
31 ID = 0.995;
32
33 //required effectiveness of the exchanger
34 E = (Tcout-Tcin)/(Thin-Tcin);
35
36 //For a condenser, Cmin/Cmax=0, and from Fig. 8.20,
    NTU =1.4.
37 NTU = 1.4;
38
39 //The fouling factors from Table 8.2 are 0.0005 h
    ft2 F/Btu for both sides of the tubes.
40 //F-Factor
41 F = 0.0005;
42
43 //The overall design heat-transfer coefficient in
    Btu/h ft2 F per unit outside area of tube is,
    from Eq. (8.6)
44 U = 1/(1/hsteam+F+(OD/((2*12)*60))*log(OD/ID)+(F*OD)
    /ID+OD/(hwater*ID));
45
46 //The total area A is 20*pi*D*L, and since U*A/Cmin
    =1.4
47
48 disp("The length of the tube in ft is")
49 //The length of the tube in ft
50 L = (((1.4*mw)*c)*12)/(((Tcin*%pi)*OD)*U)

```

Scilab code Exa 8.5 Theoretical Problem

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter - 8 Example # 8.5 ")
11
12 disp("There is no computations in this example.")
13 disp("It is theoretical")
```

Chapter 9

Heat Transfer by Radiation

Scilab code Exa 9.1 Analysis of Tungsten Filament

```
1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 ieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
      Frank Kreith , Raj M Manglik and Mark S Bohn ,
      Chapter 9 , Example 1")
10 //Temperature of the tungsten filament in Kelvin
11 T=1400;
12
13 disp("a)Wavelength at which the monochromatic
      emissive power of the given tungsten filament is
      maximum in meters")
14 //Wavelength in m
15 lamda_max=2.898e-3/T
16
17 disp("b)Monochromatic emissive power at calculated
```

```

        maximum wavelength in W/m^3")
18 //Emissive power in W/m3
19 Eb_max=12.87e-6*(T^5)
20
21 //Given wavelength in meters
22 lamda=5e-6;
23 //Product of wavelength and temperature in m-K
24 lamda_T=lamda*T;
25
26 disp("c) Monochromatic emissive power at given
        wavelength in W/m^3")
27 //Emissive power in W/m3
28 Eb_lamda=Eb_max*(2.898e-3/(lamda_T))^5*(((%e^4.965)
        -1)/((%e^(0.014388/lamda_T)-1)))
29 disp("Thus , Monochromatic emissive power at 5e-6 m
        wavelength is 25.4% of the Monochromatic emissive
        power at maximum wavelength")

```

Scilab code Exa 9.2 Transmission of Solar Radiation

```

1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 ieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
        Frank Kreith , Raj M Manglik and Mark S Bohn ,
        Chapter 9, Example 2")
10 //Temperature at which sun is radiating as a
        blackbody in K
11 T=5800;
12

```

```

13 //Lower limit of wavelength for which glass is
    transparent in microns
14 lamda_l=0.35;
15 //lower limit of product of wavelength and
    temperature in micron-K
16 lamda_l_T=lamda_l*T;
17 //Lower limit of wavelength for which glass is
    transparent in microns
18 lamda_u=2.7;
19 //lower limit of product of wavelength and
    temperature in micron-K
20 lamda_u_T=lamda_u*T;
21
22 // For lamda_T= 2030, ratio of blackbody emission
    between zero and lamda_l to the total emission in
    terms of percentage
23 r_l=6.7;
24 // For lamda_T= 15660, ratio of blackbody emission
    between zero and lamda_u to the total emission in
    terms of percentage
25 r_u=97;
26
27 //Total radiant energy incident upon the glass from
    the sun in the wavelength range between lamda_l
    and lamda_u
28 total_rad=r_u-r_l;
29 disp("Percentage of solar radiation transmitted
    through the glass in terms of percentage")
30 rad_trans=total_rad*0.92 //Since it is given that
    silica glass transmits 92% of the incident
    radiation

```

Scilab code Exa 9.3 Solid Angle Calculation

1


```

2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 iieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
      Frank Kreith , Raj M Manglik and Mark S Bohn,
      Chapter 9, Example 3")
10 //Area of the flat black surface in m^2
11 A_1=10e-4;
12 //Radiation emitted by the flat black surface in W/m
    ^ sr
13 I_1=1000;
14 // Another surface having same area as A1 is placed
    relative to A1 such that length of radiation ray
    connecting dA_1 and dA_2 in meters
15 r=0.5;
16 //Area in m^2
17 A_2=10e-4;
18 // Since both areas are quite small, they can be
    approximated as differential surface areas and
    the solid angle can be calculated as
19 //d_omega21=dA_n2/r^2 where dA_n2 is the projection
    of A2 in the direction normal to the incident
    radiation for dA_1, thus
20
21 //Angle between the normal n_2 ant the radiation ray
    connecting dA_1 and dA_2
22 theta_2=30;
23
24 //Therefore solid angle in sr
25 d_omega21=(A_2*cosd(theta_2)/(r^2));
26
27 disp("Irradiation of A_2 by A_1 in watt")
28 //Irradiation in W
29 q_r12= I_1*A_1*cosd(90-theta_2)*d_omega21

```

Scilab code Exa 9.4 Emissivity of Aluminium Surface

```
1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 ieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
      Frank Kreith , Raj M Manglik and Mark S Bohn ,
      Chapter 9, Example 4")
10 //Hemispherical emissivity of an aluminum paint at
      wavelengths below 3 microns
11 epsilon_lambda_1=0.4;
12 //Hemispherical emissivity of an aluminum paint at
      longer wavelengths
13 epsilon_lambda_2=0.8;
14 //At room temperature 27 degree celcius , product of
      lamda and T in micron-K
15 lamda_T_1=3*(27+273);
16 //At elevated temperature 527 degree celcius ,
      product of lamda and T in micron-K
17 lamda_T_2=3*(527+273);
18 //From Table 9.1
19 // For lamda_T_1 , ratio of blackbody emission
      between zero and lamda_l to the total emission
20 r_1=0.00016;
21 // For lamda_T_2 , ratio of blackbody emission
      between zero and lamda_u to the total emission
22 r_2=0.14;
23 disp("Thus, the emissivity at 27 C")
24 //Emissivity
```

```

25 epsilon=0.8
26 disp("emissivity at 527 C")
27 //Emissivity at higher temp.
28 epsilon=(r_2*epsilon_lamda_1)+(epsilon_lamda_2*0.86)
29 disp("The reason for the difference in the total
      emissivity is that at the higher temperature, the
      percentage of the total emissive power in the low
      -emittance region of the paint is appreciable,
      while at the lower temperature practically all
      the radiation is emitted at wavelengths above 3
      microns")

```

Scilab code Exa 9.5 Absorptivity of Aluminium Surface

```

1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 ieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
      Frank Kreith , Raj M Manglik and Mark S Bohn ,
      Chapter 9, Example 5")
10 //Temperature of the sun in K
11 T=5800;
12 //For the case of Solar irradiation , value of the
      product of lamda and T in micron-K
13 lamda_T_1=3*T; // value of lamda is taken from
      Example 9.4
14 //From table 9.1
15 // For lamda_T_1 , ratio of blackbody emission
      between zero and lamda_1 to the total emission
16 r_1=0.98;

```

```

17 //This means that 98% of the solar radiation falls
    below 3 microns
18 //Hemispherical emissivity of an aluminum paint at
    wavelengths below 3 microns
19 epsilon_lambda_1=0.4;
20 //Hemispherical emissivity of an aluminum paint at
    longer wavelengths
21 epsilon_lambda_2=0.8;
22 disp("Effective absorptivity for first case")
23 //Effective absorptivity
24 alpha_1=(r_1*epsilon_lambda_1)+(epsilon_lambda_2*0.02)
25 //For the case second with source at 800 K, value of
    the product of lambda and T in micron-K
26 lambda_T_2=3*800;
27 // For lambda_T_2, ratio of blackbody emission
    between zero and lambda_1 to the total emission
28 r_2=0.14;
29 disp("Effective absorptivity for second case")
30 //Effective absorptivity
31 alpha_2=(r_2*epsilon_lambda_1)+(epsilon_lambda_2*0.86)

```

Scilab code Exa 9.6 Analysis of Painted Surface

```

1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 iieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
    Frank Kreith , Raj M Manglik and Mark S Bohn ,
    Chapter 9 , Example 6")
10 //Stefan Boltzmann constant in W/m^2 K^4

```

```

11 sigma=5.67e-8;
12 //Temperature of the painted surface in K
13 T=1000;
14 //Temperature of the sun in K
15 T_s=5800;
16 //Given, below 2 microns the emissivity of the
    surface is 0.3,so
17 lamda_1=2; //wavelength in microns
18 epsilon_1=0.3; //emissivity
19
20 //Given, between 2 and 4 microns emmissivity is 0.9,
    so
21 lamda_2=4; //wavelength in microns
22 epsilon_2=0.9; //emissivity
23
24 //Given, above 4 microns emmissivity is 0.5, so
25 epsilon_3=0.5; //emissivity
26
27 //value of the product of lamda_1 and T in micron-K
28 lamda_1_T=2e-3*T;
29
30 //From table 9.1
31 // For lamda_1_T, ratio of blackbody emission
    between zero and lamda_1 to the total emission
32 r_1=0.0667; //1st ratio
33
34 //value of the product of lamda_2 and T in micron-K
35 lamda_2_T=2e-3*T;
36 //From table 9.1
37 // For lamda_2_T, ratio of blackbody emission
    between zero and lamda_1 to the total emission
38 r_2=0.4809; //2nd ratio
39
40 disp("a) Effective emissivity over the entire
    spectrum")
41 //Effective emissivity
42 epsilon_bar=epsilon_1*r_1+epsilon_2*(r_2-r_1)+
    epsilon_3*(1-r_2)

```

```

43
44 disp("b) Emissive power in W/m^2")
45 //Emissive power in W/m^2
46 E=epsilon_bar*sigma*T^4
47
48 //value of the product of lamda_1 and T_s in micron-
    K
49 lamda_1_T_s=2e-3*T_s;
50 //From table 9.1
51 // For lamda_1_T_s, ratio of blackbody emission
    between zero and lamda_1 to the total emission
52 r_1_s=0.941;
53 //value of the product of lamda_2 and T_s in micron-
    K
54 lamda_2_T_s=2e-3*T_s;
55 //From table 9.1
56 // For lamda_2_T_s, ratio of blackbody emission
    between zero and lamda_1 to the total emission
57 r_2_s=0.99;
58 disp("c) Average solar absorptivity")
59 //Average solar absorptivity
60 alpha_s=epsilon_1*r_1_s+epsilon_2*(r_2_s-r_1_s)+
    epsilon_3*(1-r_2_s)

```

Scilab code Exa 9.7 Analysis of an Oxidised Surface

```

1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 ieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,

```

```

    Frank Kreith , Raj M Manglik and Mark S Bohn ,
    Chapter 9, Example 7")
10 //Temperature of the oxidised surface in Kelvin
11 T=1800;
12 //Area of the oxidised surface in m^2
13 A=5e-3;
14 //Stefan Boltzmann constant in W/m^2 K^4
15 sigma=5.67e-8;
16 disp("a)Emissivity perpendicular to the surface")
17 //Emissivity
18 epsilon_zero=0.70*cosd(0)
19 disp("b)Hemispherical emissivity")
20 //Hemispherical emissivity
21 epsilon_bar=((-1.4)/3)*((cosd(90))^3-(cosd(0))^3)
22 disp("c)Emissive Power in Watt")
23 //Emissive Power in W
24 E=epsilon_bar*A*sigma*T^4

```

Scilab code Exa 9.8 Theoretical Problem

```

1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 ieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
    Frank Kreith , Raj M Manglik and Mark S Bohn ,
    Chapter 9, Example 8")
10
11 // Theoretical Proof
12 disp("The given example is theoretical and does not
    involve any numerical computation")

```

Scilab code Exa 9.9 Shape Factor in Window Arrangement

```
1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 ieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
      Frank Kreith , Raj M Manglik and Mark S Bohn ,
      Chapter 9, Example 9")
10 //Window arrangement consists of a long opening with
      dimensions
11 //Height in meters
12 h=1;
13 //Length in meters
14 l=5;
15 //width of table in meters
16 w=2;
17 //Assuming that window and table are sufficiently
      long and applying crossed string method, we get
18 //Distance ab in m
19 ab=0;
20 //Distance cb in m
21 cb=w;
22 //Distance ad in m
23 ad=h;
24 //Distance cd in m
25 cd=sqrt(1);
26
27 disp("Shape factor between the window and the table"
      )
```



```
28 //Shape factor between the window and the table
29 F_12=0.5*(ad+cb-cd)
```

Scilab code Exa 9.10 Shape Factor Computation

```
1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 ieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
      Frank Kreith , Raj M Manglik and Mark S Bohn ,
      Chapter 9, Example 8")
10 //Window area in ft^2
11 A1=6*20;
12 //Second area in ft^2
13 A2=4*20;
14 //Assuming A5=A1+A2
15 //Area in ft^2
16 A5=A1+A2;
17
18 //From Fig. 9.27
19 //Shape Factors required
20 F56=0.19;
21 F26=0.32;
22 F53=0.08;
23 F23=0.19;
24
25 disp("Shape factor")
26 //Shape factor
27 F14=(A5*F56-A2*F26-A5*F53+A2*F23)/A1
28 disp("Thus, only about 10% of the light passing
```

through the window will impinge on the floor area
A4”)

Scilab code Exa 9.11 Liquid Oxygen in Spherical Container

```
1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter – 9 Example # 9.11 ")
11
12 //Absolute boiling temperature of liquid oxygen in R
13 T1 = 460-297;
14 //Absolute temperature of sphere in R
15 T2 = 460+30;
16 //Diameter of inner sphere in ft
17 D1 = 1;
18 //Area of inner sphere in ft2
19 A1 = (%pi*D1)*D1;
20 //Diameter of outer sphere in ft
21 D2 = 1.5;
22 //Area of outer sphere in ft2
23 A2 = (%pi*D2)*D2;
24 //Stefans constant
25 sigma = 0.1714;
26 //Emissivity of Aluminium
27 epsilon1 = 0.03; //Sphere1
28 epsilon2 = 0.03; //Sphere2
29
```

```

30 //Using Eq. 9.74
31 disp("Rate of heat flow by radiation to the oxygen
      in Btu/h is")
32 //Rate of heat flow by radiation to the oxygen in
      Btu/h
33 q = ((A1*sigma)*((T1/100)^4-(T2/100)^4))/(1/epsilon1
      +(A1/A2)*((1-epsilon2)/epsilon2))

```

Scilab code Exa 9.12 Radiative Exchange Between Cone Surfaces

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter – 9 Example # 9.12 ")
11
12 // Provide all given inputs and constants of the
      problem
13
14 // Stefan Boltzmann constant (W/m^2/K^4)
15 SIGMA = 0.0000000567;
16
17 //Area(1)=R1^2*pi in m2
18 AR(1,1) = 9*%pi;
19
20 // The physical parameters, e.g., shape factor and
      emissivity, are evaluated.
21
22 //All F(i,j) are shape factors.

```

```

23 F(1,1) = 0;
24 F(1,2) = 0.853;
25 F(1,3) = 0.147;
26 F(2,1) = 0.372;
27 F(2,2) = 0.498;
28 F(2,3) = 0.13;
29 F(3,1) = 0.333;
30 F(3,2) = 0.667;
31 F(3,3) = 0;
32
33 //ESP are emissivity given in the problem
34 ESP(1,1) = 0.6;
35 ESP(1,3) = 0.9;
36
37 //Temperature in degree K
38 T(1,1) = 1200;
39 //Temperature in degree K
40 T(1,3) = 600;
41
42 //Emissive Power of blackbody in W/m2
43 EB(1,1) = SIGMA*(T(1)^4);
44 //Emissive Power of blackbody in W/m2
45 EB(1,3) = SIGMA*(T(3)^4);
46
47 // The values of the elements of the coefficient
   matrix A in the equation
48 // [A][X]=[B] are specified
49 A(1,1) = 1-F(1,1)+ESP(1)/(1-ESP(1));
50 A(1,2) = -F(1,2);
51 A(1,3) = -F(1,3);
52 A(2,1) = -F(2,1);
53 A(2,2) = 1-F(2,2);
54 A(2,3) = -F(2,3);
55 A(3,1) = -F(3,1);
56 A(3,2) = -F(3,2);
57 A(3,3) = 1-F(3,3)+ESP(3)/(1-ESP(3));
58
59 // The values of the right-hand side vector B are

```

```

        specified.
60 B(1,1) = (EB(1)*ESP(1))/(1-ESP(1));
61 B(1,2) = 0;
62 B(3) = (EB(3)*ESP(3))/(1-ESP(3));
63
64 // The inversion routine is used to solve for X
65 disp("Net radiative exchange between the top and
        bottom surface in W")
66 //Net radiative exchange between the top and bottom
        surface in W
67 X = inv(A)*B' // solutions for J

```

Scilab code Exa 9.13 Temperature of Surface of Cone

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
        Kreith et. al Chapter - 9 Example # 9.13 ")
11
12 // Provide all given inputs and constants of the
        problem
13 SIGMA = 0.0000000567; // Stefan-Boltzmann constant (W
        m^2 K^4)
14
15 //all F(I,J) are shape factor
16 F(1,1) = 0;
17 F(1,2) = 0.853;
18 F(1,3) = 0.147;

```

```

19 F(2,1) = 0.372;
20 F(2,2) = 0.498;
21 F(2,3) = 0.13;
22 F(3,1) = 0.333;
23 F(3,2) = 0.667;
24 F(3,3) = 0;
25
26 //Area(1)=R1^2*pi in m2
27 AR(1,1) = 9*%pi;
28
29 //ESP are total hemispheric emissivity in W/m2
30 ESP(1,1) = 0.6;
31 ESP(1,3) = 0.9;
32
33 //Heat exchange in W
34 Q1 = 300000;
35
36 //Temperature in degree K
37 T(1,3) = 600;
38
39 //EB blackbody emissive powers in W/m2
40 EB(1,3) = SIGMA*(T(3)^4);
41
42 // Evaluate elements of coefficient matrix
43 A(1,1) = 1-F(1,1);
44 A(1,2) = -F(1,2);
45 A(1,3) = -F(1,3);
46 A(2,1) = -F(2,1);
47 A(2,2) = 1-F(2,2);
48 A(2,3) = -F(2,3);
49 A(3,1) = 0;
50 A(3,2) = 0;
51 A(3,3) = 1;
52
53 // Evaluate elements of right hand side matrix
54 B(1,1) = Q1/AR(1);
55 B(1,2) = 0;
56 B(3) = EB(3);

```

```

57
58 // solve the system of equations for X
59 X = inv(A)*B';
60
61 //Required temperature in degree K
62 T(1) = ((X(1)+(Q1*(1-ESP(1)))/(AR(1)*ESP(1)))/SIGMA)
        ^0.25;
63 //solution for temperatures
64 disp("Temperature of surface 1 for the cone in
        degree K")
65 T1 = T(1)//Value for the required temperature in K

```

Scilab code Exa 9.14 Heat Transfer Between Parallel Plates

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
        Kreith et. al Chapter - 9 Example # 9.14 ")
11
12 //Absolute temperature of first plate in degree R
13 Ta = 2040+460;
14 //Absolute temperature of second plate in degree R
15 Tb = 540+460;
16 //Stefans constant
17 sigma = 0.1718;
18
19 //For first radiation band, heat transfer is
        calculated

```

```

20 //Emissivity of A
21 epsilonA = 0.1;
22 //Emissivity of B
23 epsilonB = 0.9;
24 //Shape factor
25 Fab = 1/(1/epsilonA+1/epsilonB-1);
26 //The percentage of the total radiation within a
    given band is obtained from Table 9.1.
27 //Coefficients of T^4
28 A = 0.375;
29 //Coefficients of T^4
30 B = 0.004;
31
32 //Rate of heat transfer in first band in Btu/h ft2
33 q1 = (Fab*sigma)*(A*((Ta/100)^4)-B*((Tb/100)^4));
34
35 //Similarly for other two bands, heat transfer in
    Btu/h ft2
36 q2 = 23000;
37 //heat transfer in Btu/h ft2
38 q3 = 1240;
39
40 disp("Total rate of radiation heat transfer in Btu/h
    ft2")
41 //heat transfer in Btu/h ft2
42 q = q1+q2+q3

```

Scilab code Exa 9.15 Emissivity of Gaseous Mixture

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception

```



```

7  ieee(1);
8
9  clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
      Kreith et. al Chapter – 9 Example # 9.15 ")
11
12 //Temperature in degree K
13 T = 800;
14 //Diameter of sphere in m
15 D = 0.4;
16 //Partial pressure of nitrogen in atm
17 PN2 = 1;
18 //Partial pressure of H2O in atm
19 PH2O = 0.4;
20 //Partial pressure of CO2 in atm
21 PCO2 = 0.6;
22
23 //The mean beam length for a spherical mass of gas
      is obtained from Table 9.7
24 //Beam length in m
25 L = (2/3)*D;
26
27 //The emissivities are given in Figs. 9.46 and 9.47
28 //Emissivity of H2O
29 epsilonH2O = 0.15;
30 //Emissivity of CO2
31 epsilonCO2 = 0.125;
32
33 //N2 does not radiate appreciably at 800 K, but
      since the total gas pressure
34 //is 2 atm, we must correct the 1-atm values for
      epsilon.
35 //From Figs. 9.48 and 9.49 the pressure correction
      factors are
36 //Pressure correction factor for H2O
37 CH2O = 1.62;
38 //Pressure correction factor for CO2
39 CCO2 = 1.12;

```

```

40
41 //From fig. 9.50
42 //Change in emissivity
43 deltaEpsilon = 0.014;
44
45 //Finally, the emissivity of the mixture can be
    obtained from Eq. (9.114):
46 disp("Emissivity of the mixture is")
47 //Emissivity of the mixture
48 epsilonMix = CH20*epsilonH20+CCO2*epsilonCO2 -
    deltaEpsilon

```

Scilab code Exa 9.16 Absorptivity of Gaseous Mixture

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer, 7th Ed. Frank
    Kreith et. al Chapter - 9 Example # 9.16 ")
11
12 //Total pressure in atm
13 Pt = 2;
14 //Temperature in degree K
15 TH20 = 500;
16 //Mean beam length in m
17 L = 0.75;
18 //Partial pressure of water vapor in atm
19 PH20 = 0.4;
20 //Source temperature in degree K

```

```

21 Ts = 1000;
22
23 //Since nitrogen is transparent, the absorption in
    the mixture is due to the water vapor alone.
24
25 //Parameters required
26 //A Parameter in atm-m
27 A = PH20*L;
28 //B Parameter in atm
29 B = (Pt+PH20)/2;
30
31 //From Figs. 9.46 and 9.48 we find
32 //For water, C factor in SI units
33 CH20 = 1.4;
34 //Emissivity of water
35 epsilonH20 = 0.29;
36
37
38 //From Eq. (9.115) the absorptivity of H2O is
39 disp("Absorptivity of H2O is")
40 alphaH20 = (CH20*epsilonH20)*((TH20/Ts)^0.45)

```

Scilab code Exa 9.17 Heat Flow From Flue Gas

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer, 7th Ed. Frank
    Kreith et. al Chapter - 9 Example # 9.17 ")

```

```

11
12 //Temperature of flue gas in degree F
13 Tgas = 2000;
14 //Inner-wall surface temperature in degree F
15 Tsurface = 1850;
16 //Partial pressure of water in atm
17 p = 0.05;
18 //Convection heat transfer coefficient in Btu/h ft2
    F
19 h = 1;
20 //Length of square duct in ft
21 L = 2;
22 //Volume in ft3
23 V = L*L;
24 //Surface area in ft2
25 A = 4*L;
26
27 //The rate of heat flow from the gas to the wall by
    convection per unit
28 //length in Btu/h ft is
29 qc = (h*A)*(Tgas-Tsurface);
30
31 //Effective beam length in m
32 L = ((0.3058*3.4)*V)/A;
33
34 //Product of partial pressure and L
35 k = p*L;
36
37 //From Fig. 9.46, for pL=0.026 and T=2000F, we find
38
39 //Emissivity
40 epsilon = 0.035;
41 //Absorptivity
42 alpha = 0.039;
43 //stefans constant
44 sigma = 0.171;
45
46 //Assuming that the brick surface is black, the net

```

```

    rate of heat flow from the gas to the wall by
    radiation is , according to Eq. (9.117)
47 qr = (sigma*A)*(epsilon*(((Tgas+460)/100)^4)-alpha
    *(((Tsurface+460)/100)^4)); //Btu/h
48
49 disp("Total heat flow from the gas to the duct in
    Btu/h")
50 //Total heat flow from the gas to the duct in Btu/h
51 q = qc+qr

```

Scilab code Exa 9.18 Estimation of True Gas Temperature

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter - 9 Example # 9.18 ")
11
12 //Emissivity
13 epsilon = 0.8;
14 //Stefan 's constant
15 sigma = 0.1714;
16 //Temperature of walls in degree F
17 Twall = 440;
18 //Temperature indicated ny thermocouple in degree F
19 Tt = 940;
20 //Heat transfer coefficient in Btu/h ft2 F
21 h = 25;
22

```

```

23 //The temperature of the thermocouple is below the
    gas temperature because the couple loses heat by
    radiation to the wall.
24
25 //Under steady-state conditions the rate of heat
    flow by radiation from the thermocouple junction
    to the wall equals the rate of heat flow by
    convection from the gas to the couple.
26
27 //Using this heat balance, q/A in Btu/h ft2
28 q = (epsilon*sigma)*(((Tt+460)/100)^4-((Twall+460)
    /100)^4);
29
30 disp("True gas temperature in degree F")
31 //True gas temperature in degree F
32 Tg = Tt+q/h

```

Scilab code Exa 9.19 Gas Temperature Measurement With Shielding

```

1
2
3 // Display mode
4 mode(0);
5
6 // Display warning for floating point exception
7 ieee(1);
8
9 clc;
10 disp("Principles of Heat Transfer , 7th Ed. Frank
    Kreith et. al Chapter - 9 Example # 9.19 ")
11
12 //Emissivity of thermocouple
13 epsilonT = 0.8;
14 //Emissivity of shield
15 epsilonS = 0.3;

```

```

16 //Stefan ' 's constant
17 sigma = 0.1714;
18 //Temperature of walls in degree F
19 Tw = 440;
20 //Temperature indicated ny thermocouple in degree F
21 Tt = 940;
22 //Heat transfer coefficient of thermocouple in Btu/h
    ft2 F
23 hrt = 25;
24 //Heat transfer coefficient of shield in Btu/h ft2 F
25 hrs = 20;
26
27 //Area for thermocouple be unity ft2
28 At = 1;
29 //Corresponding area of shield in ft2
30 As = 4; //Inside dia=4*dia of thermocouple
31
32 //From Eq. (9.76)
33 //View factors Fts and Fsw
34 Fts = 1/(((1-epsilonT)/(At*epsilonT)+1/At+(1-epsilonS
    )/(As*epsilonS)));
35 Fsw = As*epsilonS;
36
37 //Assuming a shield temperature of 900 F , we have ,
    according to Eq. (9.118)
38 //Temperature in degree F
39 Ts = 923;
40
41 //Coefficients for heat balance are as following
42 //A parameter Btu/h-F
43 A = 9.85; //A=hrt*At
44 //B parameter Btu/h-F
45 B = 13.7; //B=hrs*As
46
47 //Using heat balance
48 disp(" Correct temperature of gas in degree F")
49 //Correct temperature of gas in degree F
50 Tg = Ts+(B*(Ts-Tw)-A*(Tt-Ts))/((hrs*2)*As)

```


Chapter 10

Heat Transfer with Phase Change

Scilab code Exa 10.1 Water Boiling on Steel Surface

```
1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 ieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
      Frank Kreith , Raj M Manglik and Mark S Bohn ,
      Chapter 10, Example 1")
10 //Surface temperature of polished stainless steel
    surface in degree celcius
11 T_s=106;
12 //Boiling point of water under at atmospheric
    pressure in degree celcius
13 T_b=100;
14 //Value of empirical constant
15 C_sf=0.0132;
```

```

16 //latent heat of vaporization in J/kg
17 h_fg=2.25e6;
18 //gravitational acceleration in m/s^2
19 g=9.81;
20 //Value of proportionality factor in British
    Gravitational system
21 g_c=1;
22 //density of saturated liquid in kg/m^3
23 rho_l=962;
24 //density of saturated vapor in kg/m^3
25 rho_v=0.60;
26 //specific heat of saturated liquid in J/kg K
27 c_l=4211;
28 //prandtl number of saturated liquid
29 Pr_l=1.75;
30 //surface tension of the liquid-to-vapor interface
    in N/m
31 sigma=58.8e-3;
32 // viscosity of the liquid in kg/ms
33 mu_l=2.77e-4;
34 //Excess temperature in degree Celcius
35 delta_Tx= T_s-T_b;
36
37 disp("Heat flux from the surface to the water in W/m
    ^2")
38 //Heat flux in W./m2
39 q=(c_l*delta_Tx/(C_sf*h_fg*Pr_l))^3*mu_l*h_fg*sqrt((
    g*(rho_l-rho_v))/(g_c*sigma))
40
41 disp("Critical heat flux in W/m^2")
42 //Heat flux in W./m2
43 q_maxZ=(%pi/24)*sqrt(rho_v)*h_fg*(sigma*g*(rho_l-
    rho_v)*g_c)^0.25
44
45 disp("At 6 C excess temperature the heat flux is
    less than the critical value; therefore nucleate
    pool boiling exists")
46 disp("For the Teflon-coated stainless steel surface ,

```

```

        heat flux in W/m^2")
47 //Heat flux in W./m2
48 q=29669*(C_sf/0.0058)^3
49 disp("Thus for Teflon-coated stainless steel surface
        there is a remarkable increase in heat flux;
        however, it is still below the critical value.")

```

Scilab code Exa 10.2 Water Boiling on Polished Surface

```

1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 ieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
        Frank Kreith , Raj M Manglik and Mark S Bohn ,
        Chapter 10, Example 2")
10 //density of saturated liquid in kg/m^3
11 rho_l=962;
12 //gravitational acceleration in m/s^2
13 g=9.8;
14 //latent heat of vaporization in J/kg
15 h_fg=2250000;
16 //density of saturated vapor in kg/m^3
17 rho_v=0.60;
18 //Surface temperature of polished stainless steel
        surface in degree celcius
19 T_s=400;
20 //Value of proportionality factor in British
        Gravitational system
21 g_c=1;
22 //Boiling point of water under at atmospheric

```

```

        pressure in degree celcius
23 T_b=100;
24 //surface tension of the liquid-to-vapor interface
    in N/m
25 sigma=58.8e-3;
26 //Excess temperature in degree Celcius
27 delta_Tx= T_s-T_b;
28 //Wavelength in m from eq. 10.7
29 lamda=2*%pi*sqrt(g_c*sigma/(g*(rho_l-rho_v)));
30 //Thermal conductivity in W/mK
31 k_c=0.0249;
32 //Absolute viscosity in Ns/m^2
33 mu_c=12.1e-6;
34 //Specific heat in J/kg K
35 c_pc=2034;
36 //Heat transfer coefficient due to conduction alone
    in W/m^2 K
37 h_c=(0.59)*(((g*(rho_l-rho_v)*rho_v*(k_c^3)*(h_fg
    +(0.68*c_pc*delta_Tx)))/(lamda*mu_c*delta_Tx))
    ^0.25); // expression obtained assuming diameter
    D tending to infinity
38 //Emissivity
39 epsilon_s= 0.05; //since surface is polished and
    hence heat transfer coefficient due to radiation
    is negligible
40 disp("Heat flux in W/m^2")
41 //Heat flux in W/m^2
42 q= h_c*delta_Tx

```

Scilab code Exa 10.3 Flow of n Butyl Alcohol

```

1
2
3 // Display mode
4 mode(0);

```

```

5
6 // Display warning for floating point exception
7 iieee(1);
8
9 clc;
10 disp("Principles of Heat transfer , Seventh Edition ,
      Frank Kreith , Raj M Manglik and Mark S Bohn,
      Chapter 10, Example 3")
11 //Flow rate of n-butyl alcohol in kg/hr
12 m=161;
13 //Internal diameter of copper tube in meters
14 D=0.01;
15 //Tube wall temperature in degree C
16 T=140;
17 //surface tension in N/m
18 sigma=0.0183;
19 //Heat of vaporization in J/kg
20 h_fg=591500;
21 //atmospheric pressure boiling point in degree C
22 T_sat=117.5;
23 // saturation pressure corresponding to a saturation
      temperature of 140 C in atm
24 P_sat=2;
25 //Density of vapor in kg/m^3
26 rho_v=2.3;
27 //Viscosity of vapor in kg/m s
28 mu_v=.0143e-3;
29 //Property values for n-butyl alcohol are taken from
      Appendix 2, Table 19
30 //Density in kg/m^3
31 rho_l=737;
32 //Absolute viscosity in Ns/m^2
33 mu_l=0.39e-3;
34 //Specific heat in J/kg K
35 c_l=3429;
36 //Prandtl number
37 Pr_l=8.2;
38 //Thermal conductivity in W/m K

```

```

39 k_l=0.13;
40 //Empirical constant
41 C_sf=0.00305;// Value taken from table 10.1
42 //Mass velocity in kg/m^2 s
43 G=(m/3600)*(4/(%pi*0.01^2));
44 //Reynolds number for liquid flow
45 Re_D=(G*D)/mu_l;
46 //The contribution to the heat transfer coefficient
    due to the two-phase annular flow is [(0.023)
    *(14590)^0.8*(8.2)^0.4*16.3*(1-x)^0.8*F]
47 //Since the vapor pressure changes by 1 atm over the
    temperature range from saturation temperature to
    140 C ,so saturation pressure in N/m^2
48 delta_p_sat=101300;
49 //Therefore the contribution to the heat transfer
    coefficient from nucleate boiling is
50 //h_b=
    0.00122*[(0.163^0.79*3429^0.45*737^0.49*1^0.25)
    /(0.0183^0.5*0.39e-3^0.29*591300^0.24*2.3^0.24)
    ]*(140-117.5)^0.24*(101300)^0.75*S
51 //or h_b= 8393S
52 //Now 1/Xtt will be calculated by
53 //1/Xtt=12.86*(x/(1-x))^0.9
54 //Now a table is prepared showing stepwise
    calculations that track the increase in quality ,
    from x=0 to x=0.5,assuming that the steps delta x
    are small enough that the heat flux and other
    parameters are reasonably constant in that step
55 disp("The tube length required to reach 50% quality
    is 1.35 m")

```

Scilab code Exa 10.4 Heat Transfer Coefficients For Tube

```

1
2 // Display mode

```

```

3 mode(0);
4
5 // Display warning for floating point exception
6 iieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
      Frank Kreith , Raj M Manglik and Mark S Bohn ,
      Chapter 10, Example 4")
10 //Outer diameter of the tube in meters
11 D=0.013;
12 //Acceleration due to gravity in m/s^2
13 g=9.81;
14 //Length of the tube in meters
15 L=1.5;
16 //Temperature of saturated vapour in Kelvin
17 T_sv=349;
18 //Average tube wall temperature in Kelvin
19 T_s=325;
20 //Average temperature of the condensate film in
    degree K
21 Tf=(T_sv+T_s)/2;
22 //Thermal conductivity of liquid in W/m-K
23 k_l=0.661;
24 //Viscosity of liquid in N s/m^2
25 mu_l=4.48e-4;
26 //Dendity of liquid in kg/m^3
27 rho_l=980.9;
28 //Specific heat of liquid in J/kg K
29 c_pl=4184;
30 //Latent heat of condensation in J/kg
31 h_fg=2.349e6;
32 //Density of vapor in kg/m^3
33 rho_v=0.25;
34 //Modified latent heat of condensation in J/kg
35 h_fg_dash=h_fg+(3/8)*c_pl*(T_sv-T_s);
36
37 disp("Heat transfer coefficient for tube in

```

```

        horizontal position in W/m^2 K")
38 //Heat transfer coefficient in W/m2K
39 h_c_bar=0.725*(((rho_l*(rho_l-rho_v)*g*h_fg_dash*k_l
        ^3)/(D*mu_l*(T_sv-T_s)))^0.25)
40 disp("Heat transfer coefficient for tube in vertical
        position in W/m^2 K")
41 ////Heat transfer coefficient in W/m2K
42 h_c_bar=0.943*(((rho_l*(rho_l-rho_v)*g*h_fg_dash*k_l
        ^3)/(mu_l*(T_sv-T_s)))^0.25)

```

Scilab code Exa 10.5 Condensate Flow Determination

```

1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 ieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
        Frank Kreith , Raj M Manglik and Mark S Bohn ,
        Chapter 10, Example 5")
10 //Acceleration due to gravity in m/s^2
11 g=9.81;
12 //Length of the tube in meters
13 L=1.5;
14 //Temperature of saturated vapour in Kelvin
15 T_sv=349;
16 //Average tube wall temperature in Kelvin
17 T_s=325;
18 //Average temperature of the condensate film in
        Kelvin
19 Tf=(T_sv+T_s)/2;
20 //Thermal conductivity of liquid in W/m-K

```



```

21 k_l=0.661;
22 //Viscosity of liquid in N s/m^2
23 mu_l=4.48e-4;
24 //Dendity of liquid in kg/m^3
25 rho_l=980.9;
26 //Specific heat of liquid in J/kg K
27 c_pl=4184;
28 //Latent heat of condensation in J/kg
29 h_fg=2.349e6;
30 //Density of vapor in kg/m^3
31 rho_v=0.25;
32 //Modified latent heat of condensation in J/kg
33 h_fg_dash=h_fg+(3/8)*c_pl*(T_sv-T_s);
34
35 disp("Reynolds number at the lower edge")
36 //Reynolds number
37 Re=(4/3)*(((4*k_l*L*(T_sv-T_s)*rho_l^(2/3)*g^(1/3))
    /(mu_l^(5/3)*h_fg_dash))^0.75)
38 disp("Since the Reynolds number at the lower edge of
    the tube is below 2000, the flow of the
    condensate is laminar")

```

Scilab code Exa 10.6 Heat Transport Capability of Water

```

1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 ieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
    Frank Kreith , Raj M Manglik and Mark S Bohn ,
    Chapter 10, Example 6")

```

```

10 //Length of Heat pipe in meters
11 L_eff=0.30;
12 //Temperature of the heat pipe in degree celcius
13 T=100;
14 //Diameter of the heat pipe in meters
15 D=1e-2;
16 //Density of water at 100 degree celcius in k/m^3
17 rho=958;
18 //Viscosity of water in N s/m^2
19 mu=279e-6;
20 //surface tension of the liquid-to-vapor interface
    in N/m
21 sigma=58.9e-3;
22 //latent heat of vaporization in J/kg
23 h_fg=2.26e6;
24 //Inclination angle in degree
25 theta=30;
26 //Acceleration due to gravity in meter/sec^2
27 g=9.81;
28 //Wire diameter for wick in metres
29 d=0.0045e-2;
30 //So thickness of four layers of wire mesh
31 t=4*d;
32 //Area of the wick in m^2
33 Aw=%pi*D*t;
34 //For phosphorus-bronze,heat pipe wick pore size in
    meters
35 r=0.002e-2;
36 //For phosphorus-bronze,heat pipe wick permeability
    in m^2
37 K=0.3e-10;
38 disp("Maximum liquid flow rate in kg/sec")
39 //flow rate in kg/sec
40 m_max=((2*sigma/r)-rho*g*L_eff*sind(theta))*((rho*Aw
    *K)/(mu*L_eff))
41 disp("Maximum heat transport capability in Watt")
42 //heat transport capability in W
43 q_max=m_max*h_fg

```

Scilab code Exa 10.7 Forming of Ice Layer

```
1
2 // Display mode
3 mode(0);
4
5 // Display warning for floating point exception
6 ieee(1);
7
8 clc;
9 disp("Principles of Heat transfer , Seventh Edition ,
      Frank Kreith , Raj M Manglik and Mark S Bohn ,
      Chapter 10, Example 7")
10 //Temperature of the brine spray used for internal
      refrigeration in degree celcius
11 T_inf=-11;
12 //Required thickness of ice layer in meters
13 epsilon= 0.0025;
14 //Water-liquid temperature in degree celcius
15 T1=4.4;
16 //Liquid-surface conductance in W/m^2 K
17 h_epsilon=57;
18 //Conductance between brine and ice(including metal
      wall) in W/m^2 K
19 h_not=570;
20 //Latent heat of fusion for ice in J/Kg
21 Lf=333700;
22 //Density for ice in Kg/m^3
23 rho=918;
24 //Thermal conductivity for ice in W/m K
25 k=2.32;
26 //Freezing point temperature in degree K
27 Tfr=0;
28 //Dimensionless R, T, epsilon and t are as follows
```

```

29 //R plus parameter
30 R_plus= h_epsilon/h_not;
31 //T plus parameter
32 T_plus= (T1-Tfr)/(Tfr-T_inf);
33 //Epsilon plus parameter
34 Epsilon_plus= h_not*epsilon/k;
35 //t plus parameter
36 t_plus=(Epsilon_plus/(R_plus*T_plus))-((1/(R_plus*
      T_plus)^2)*log(1+(R_plus*T_plus*Epsilon_plus/(1+
      R_plus*T_plus))))
37
38 disp("Time taken for 0.25cm thick ice layer
      deposition in sec")
39 //time in seconds
40 t=t_plus*rho*Lf*k/((h_not)^2*(Tfr-T_inf))

```
